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(54) **PRESSURE RELIEF APPARATUS FOR USE WITH FUEL DELIVERY SYSTEMS**

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USPC ..... 220/203.01, 203.06, 203.07, 203.19, 220/203.22, 203.25, 303, 228, 231, 220/DIG. 32, DIG. 33

See application file for complete search history.

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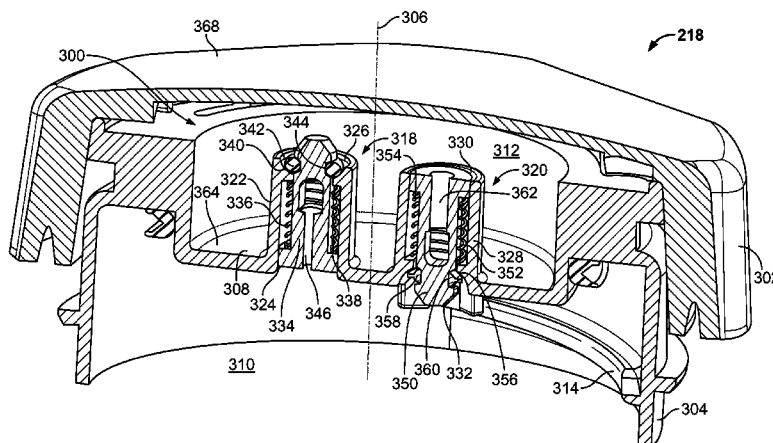
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(57)

**ABSTRACT**

Pressure relief apparatus for use with fuel delivery systems are described herein. An example pressure relief apparatus includes a pressure relief system coupled to a body of a fuel cap to define a first side of the body and a second side of the body. The pressure relief system comprises a plurality of fluid valves to enable fluid flow from the first side of the body to the second side of the body when a first pressure differential across the pressure relief system from the first side to the second side is greater than a first reference pressure and to enable fluid flow from the second side of the body to the first side of the body when a second pressure differential across the pressure relief system from the second side to the first side is greater than a second reference pressure.

**23 Claims, 15 Drawing Sheets**



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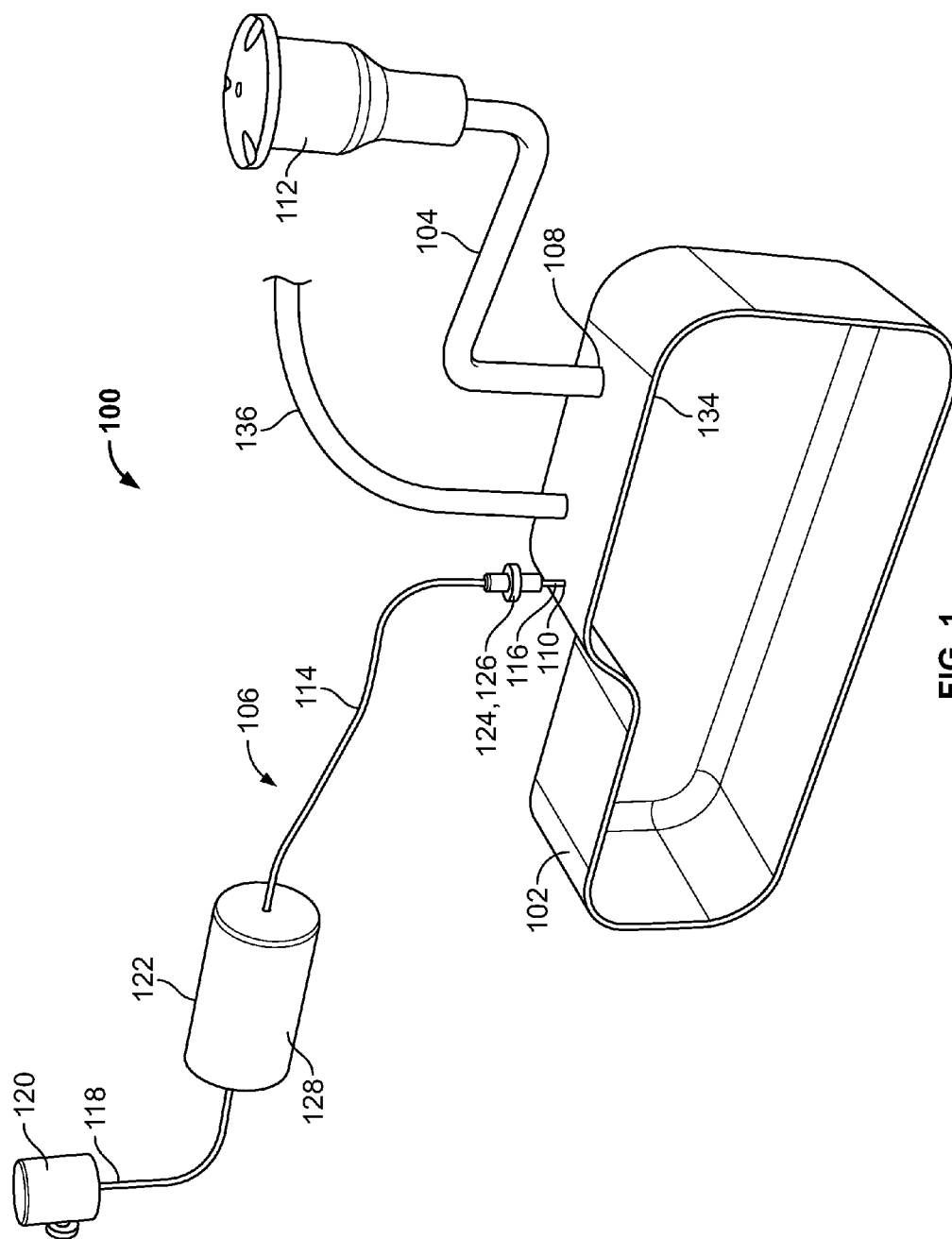
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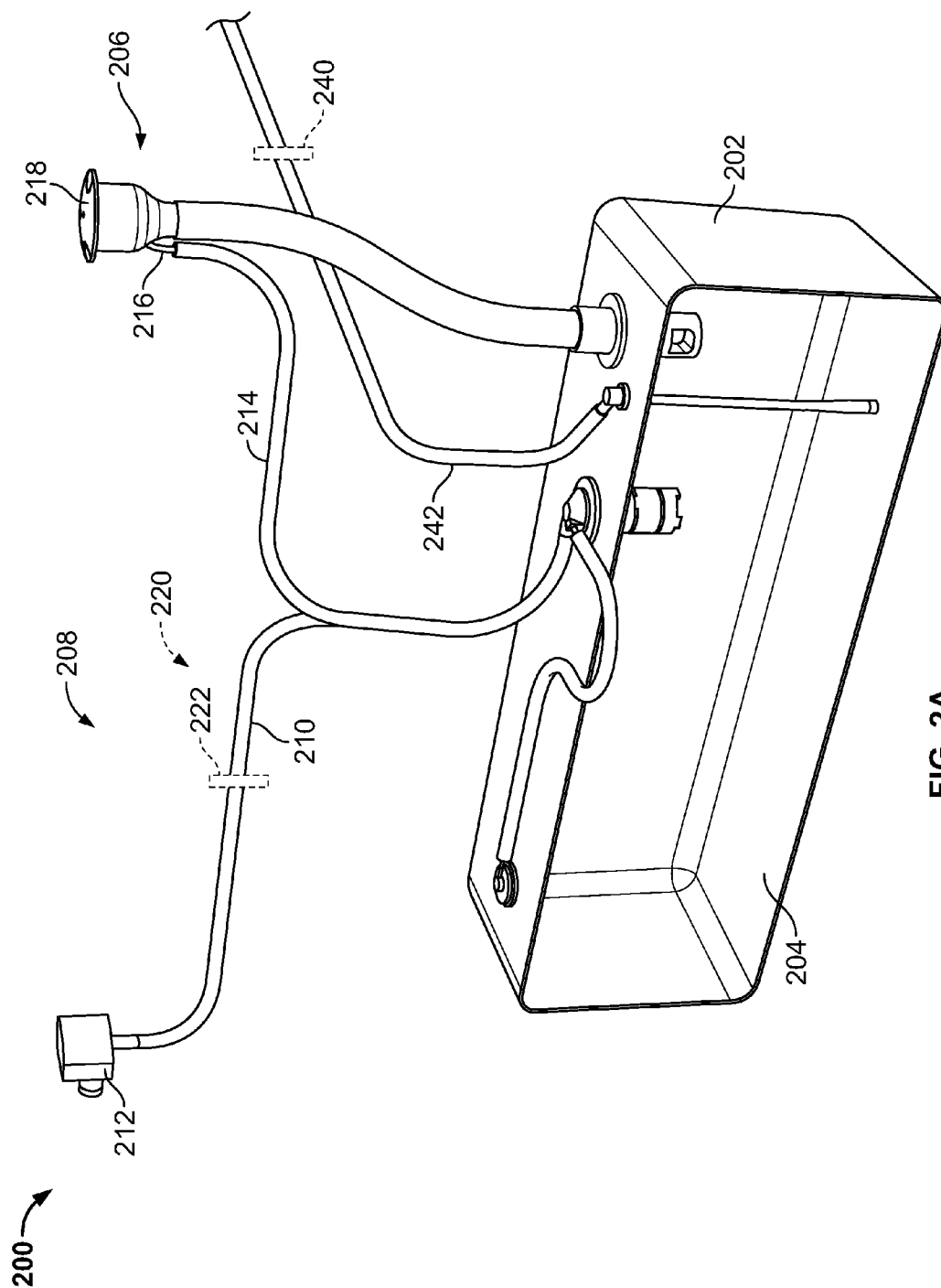


FIG. 2A

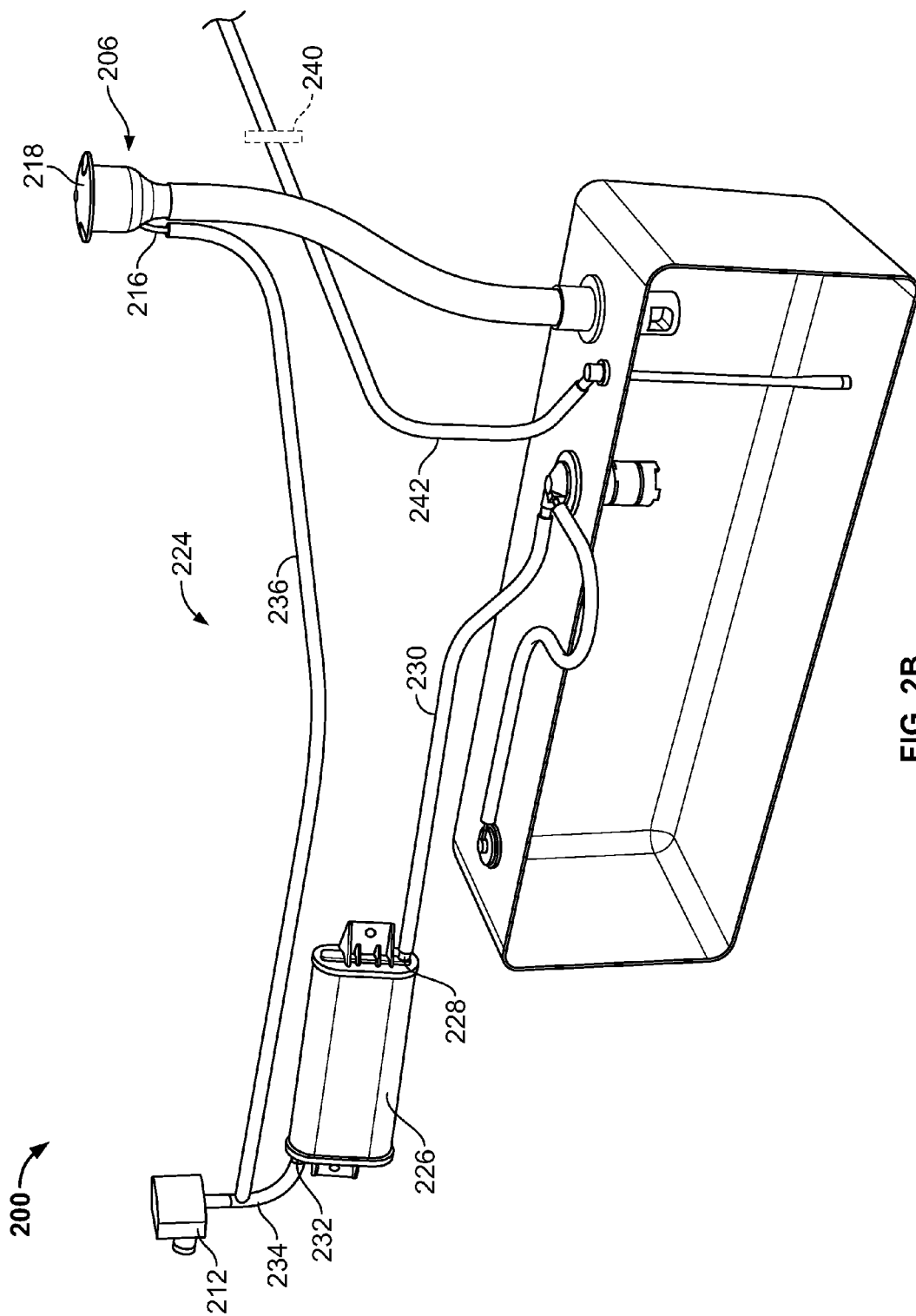
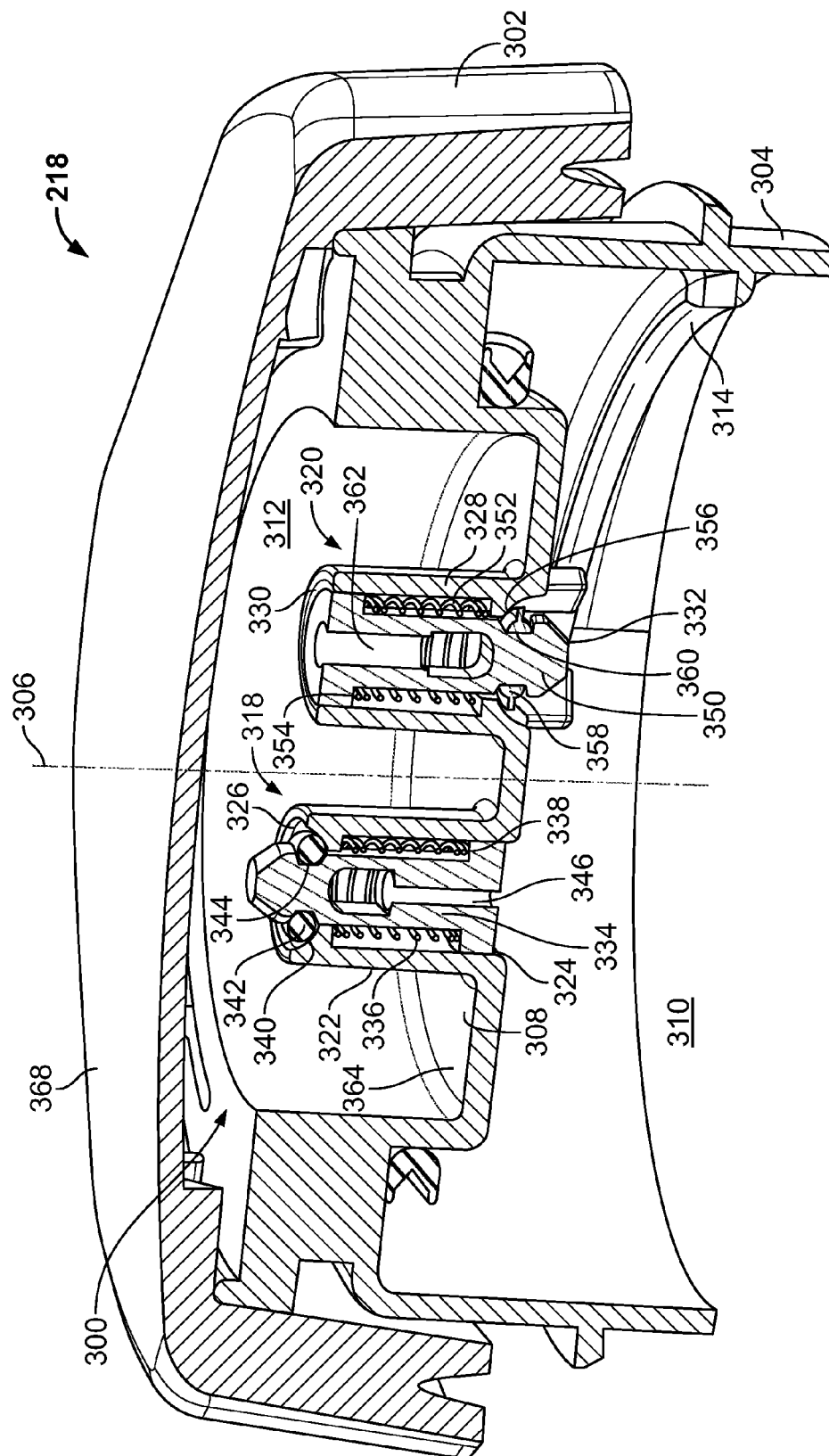


FIG. 2B



**FIG. 3A**

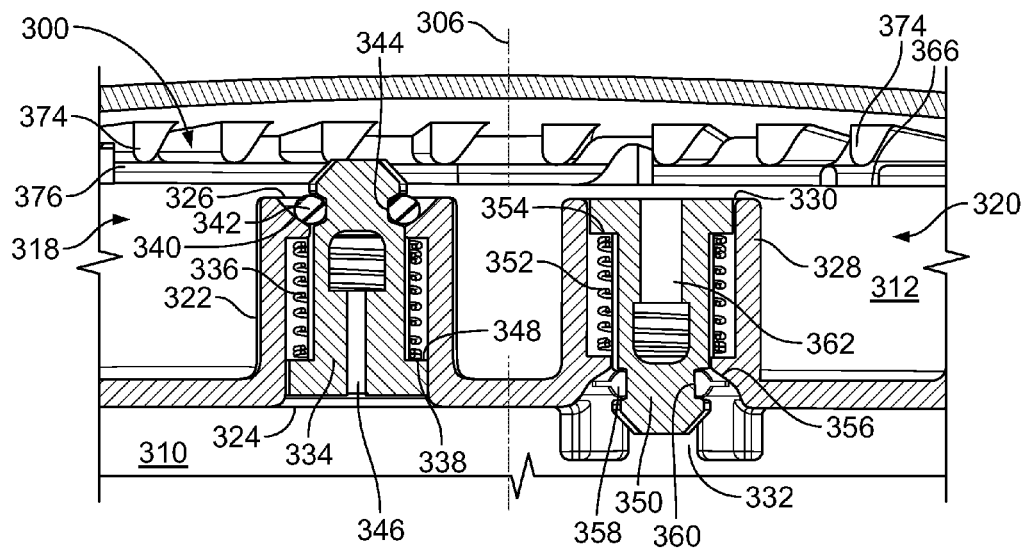


FIG. 3B

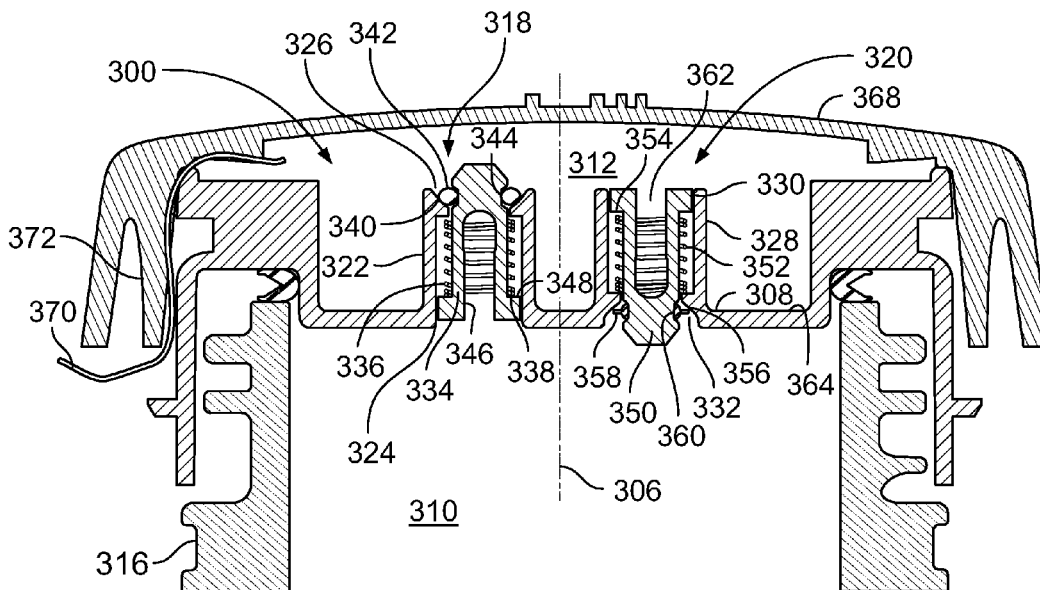


FIG. 3C

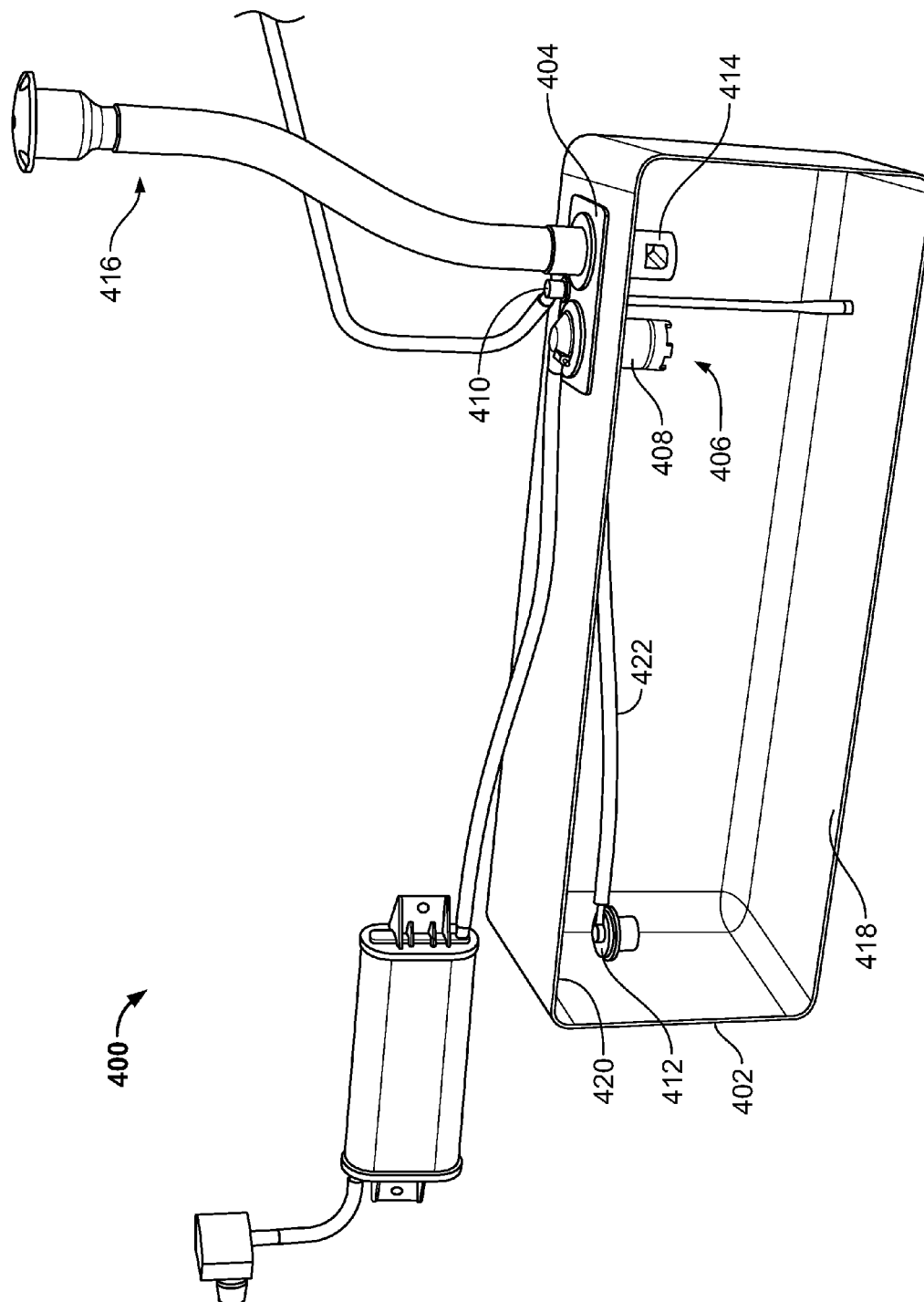


FIG. 4A



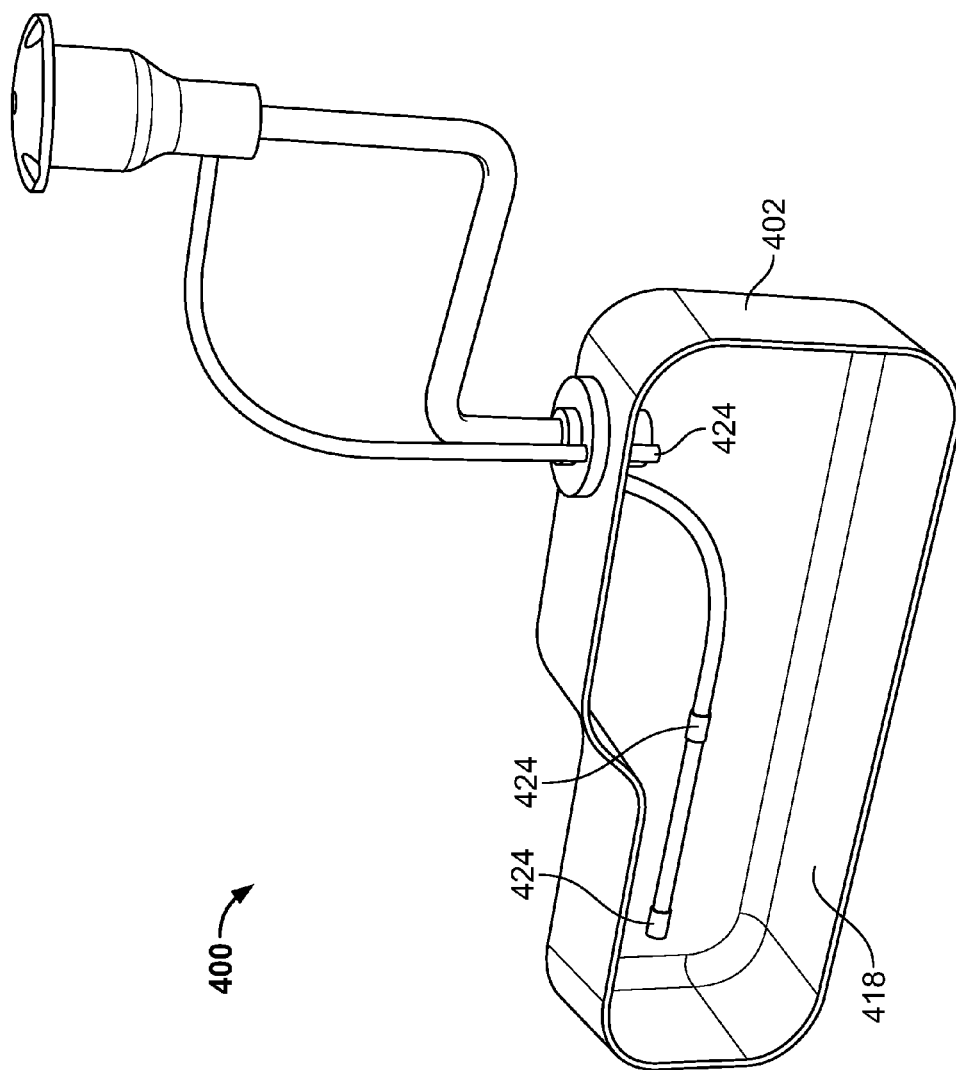


FIG. 4B

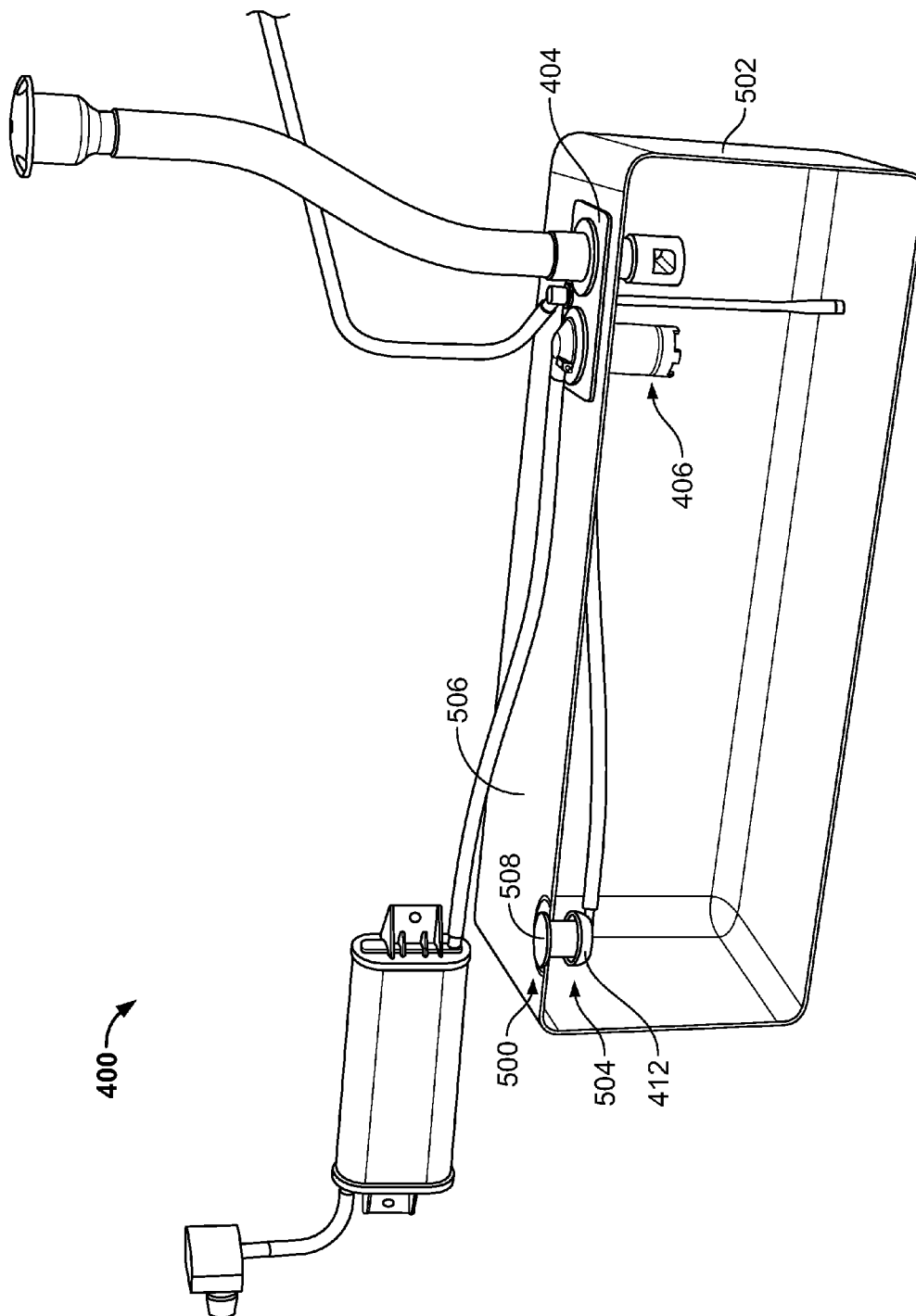
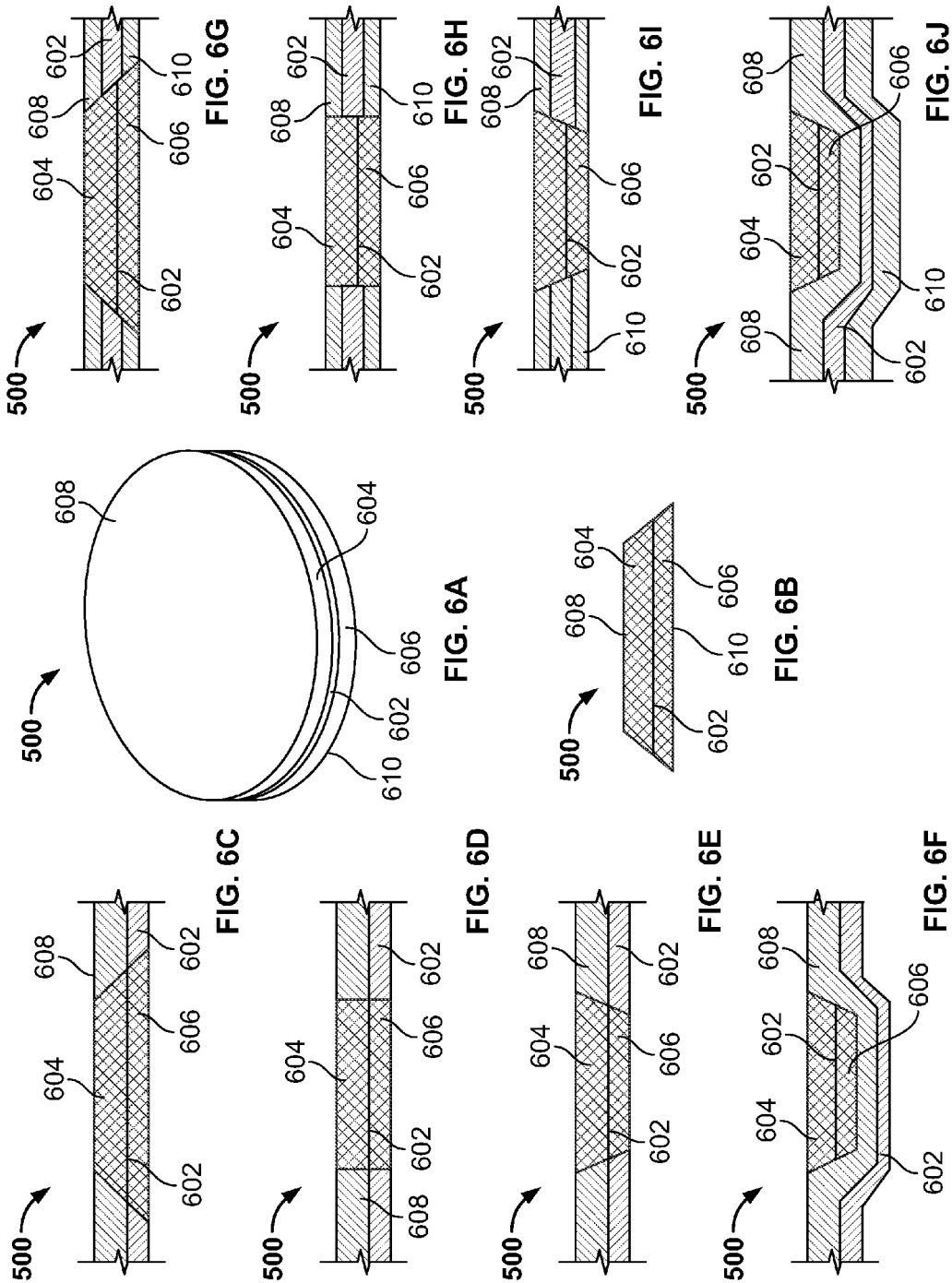
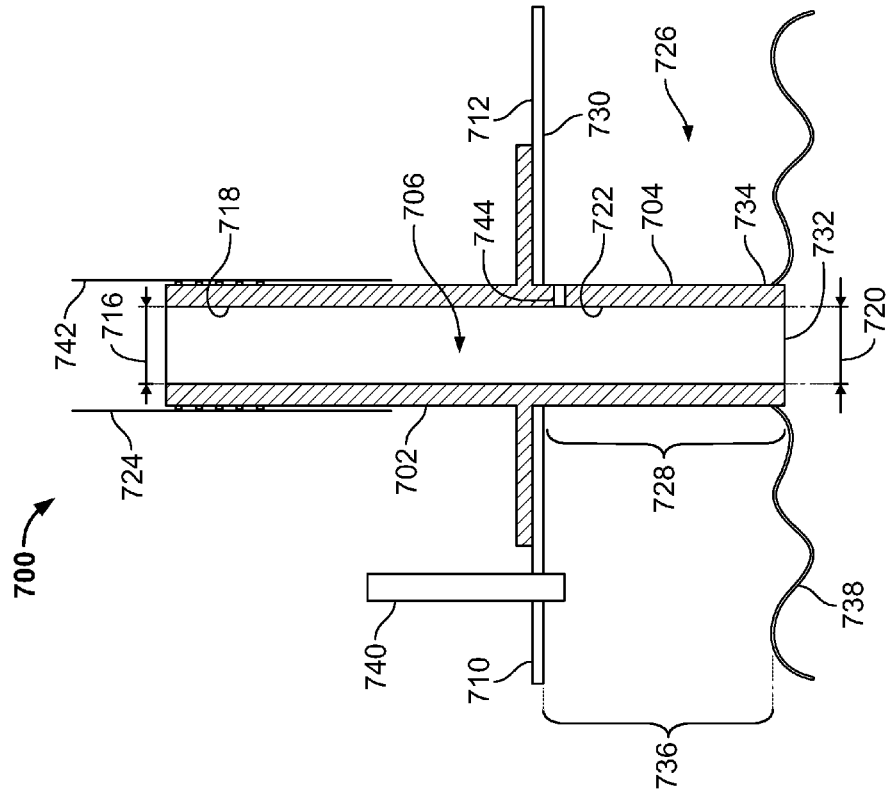
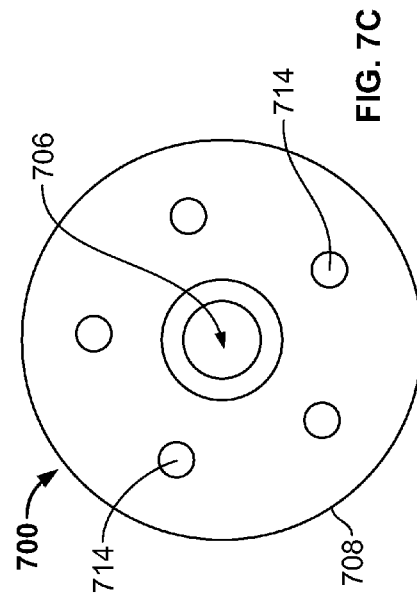
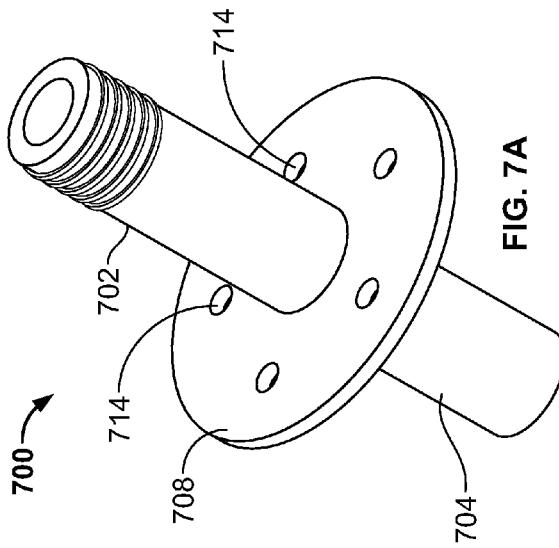


FIG. 5





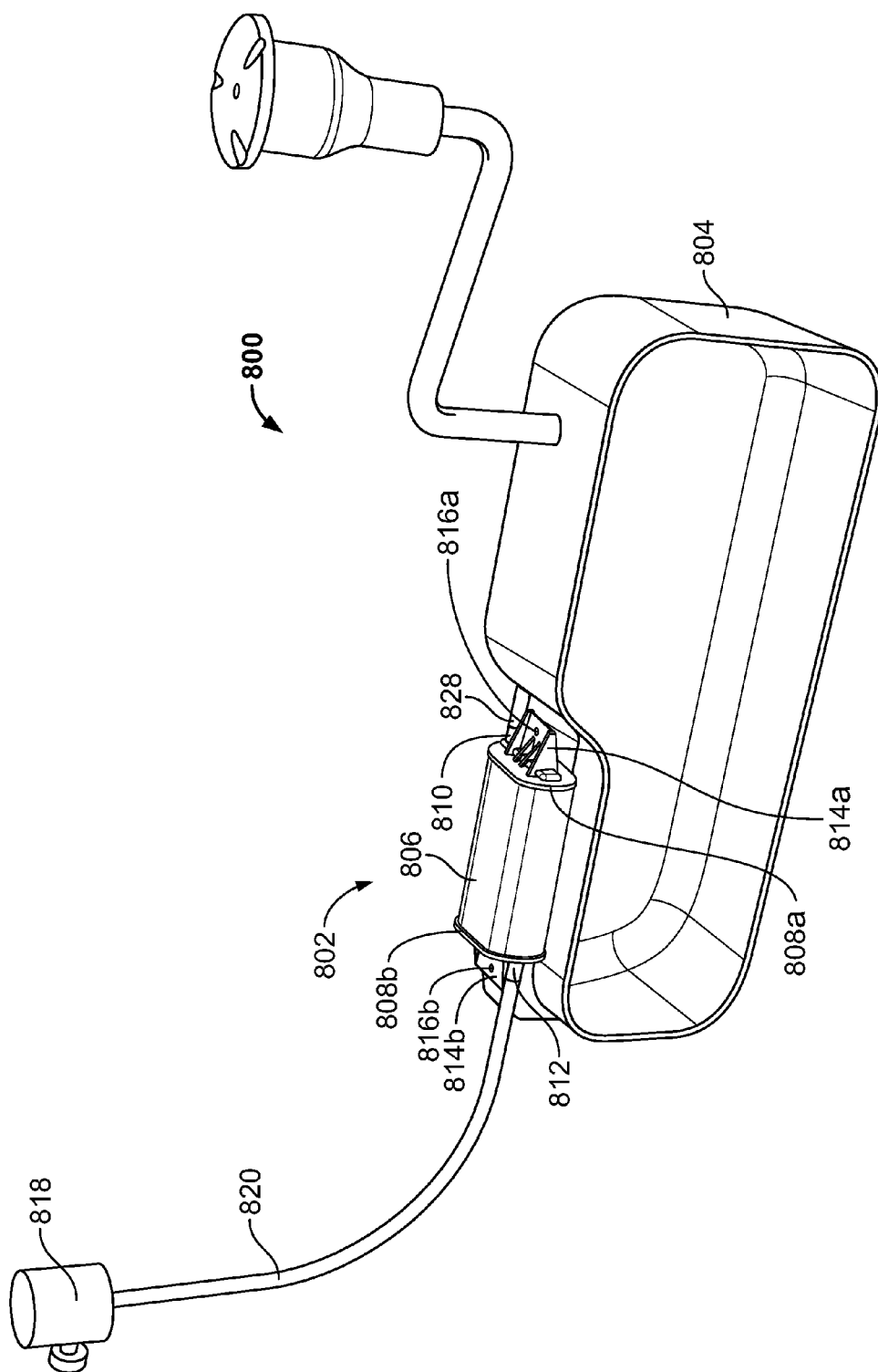


FIG. 8A

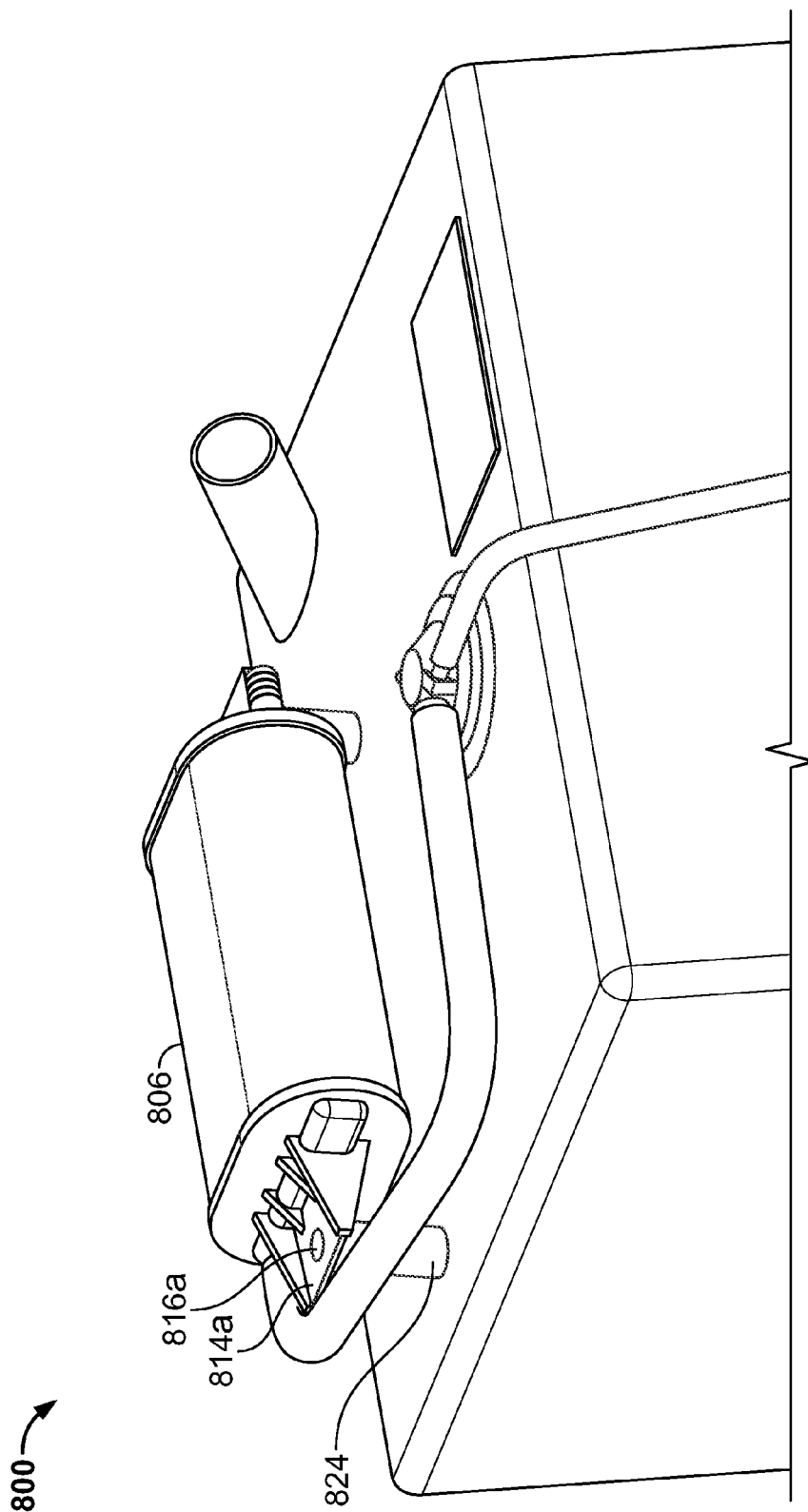


FIG. 8B

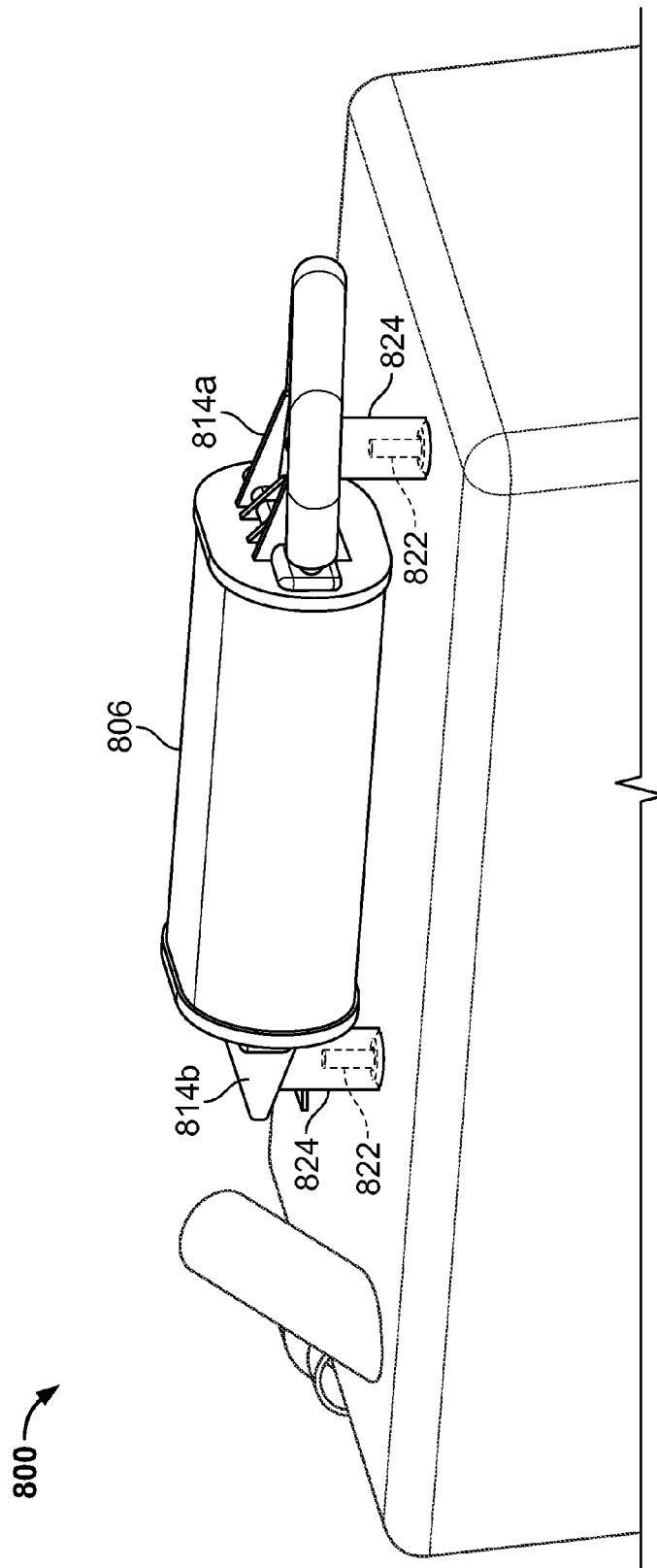


FIG. 8C

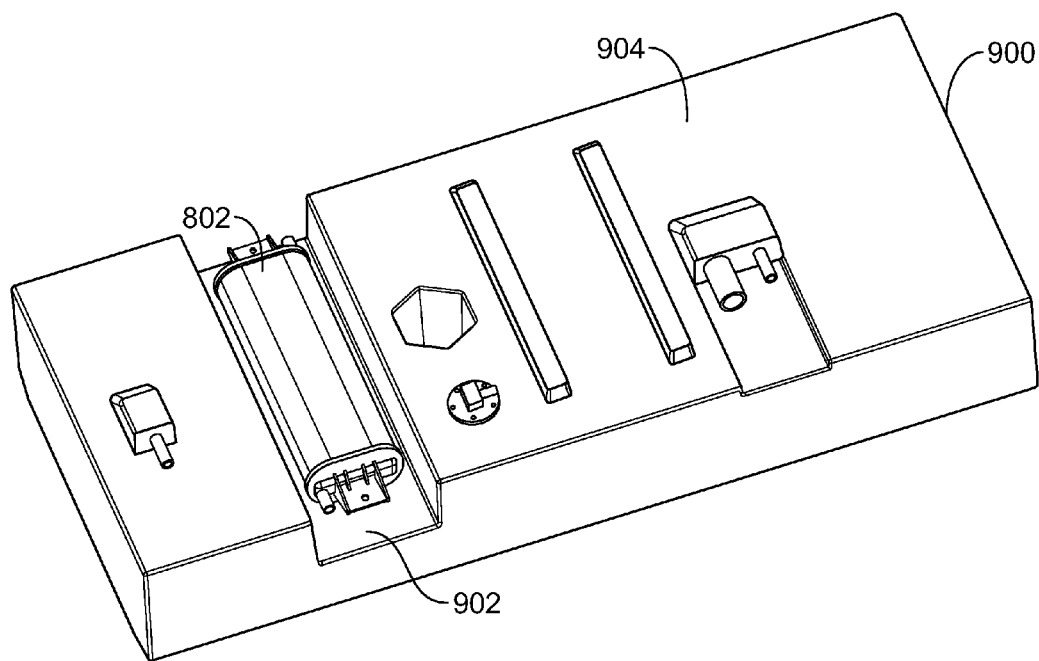


FIG. 9A

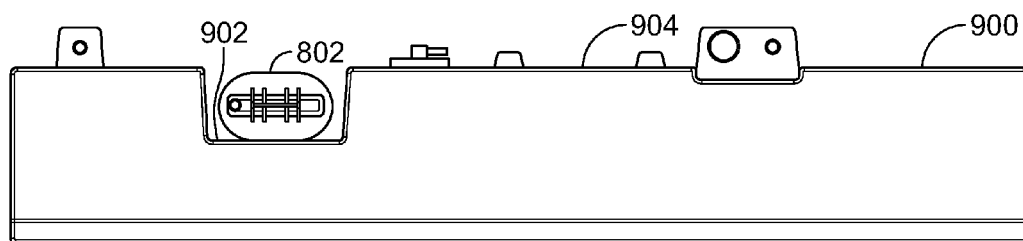


FIG. 9B



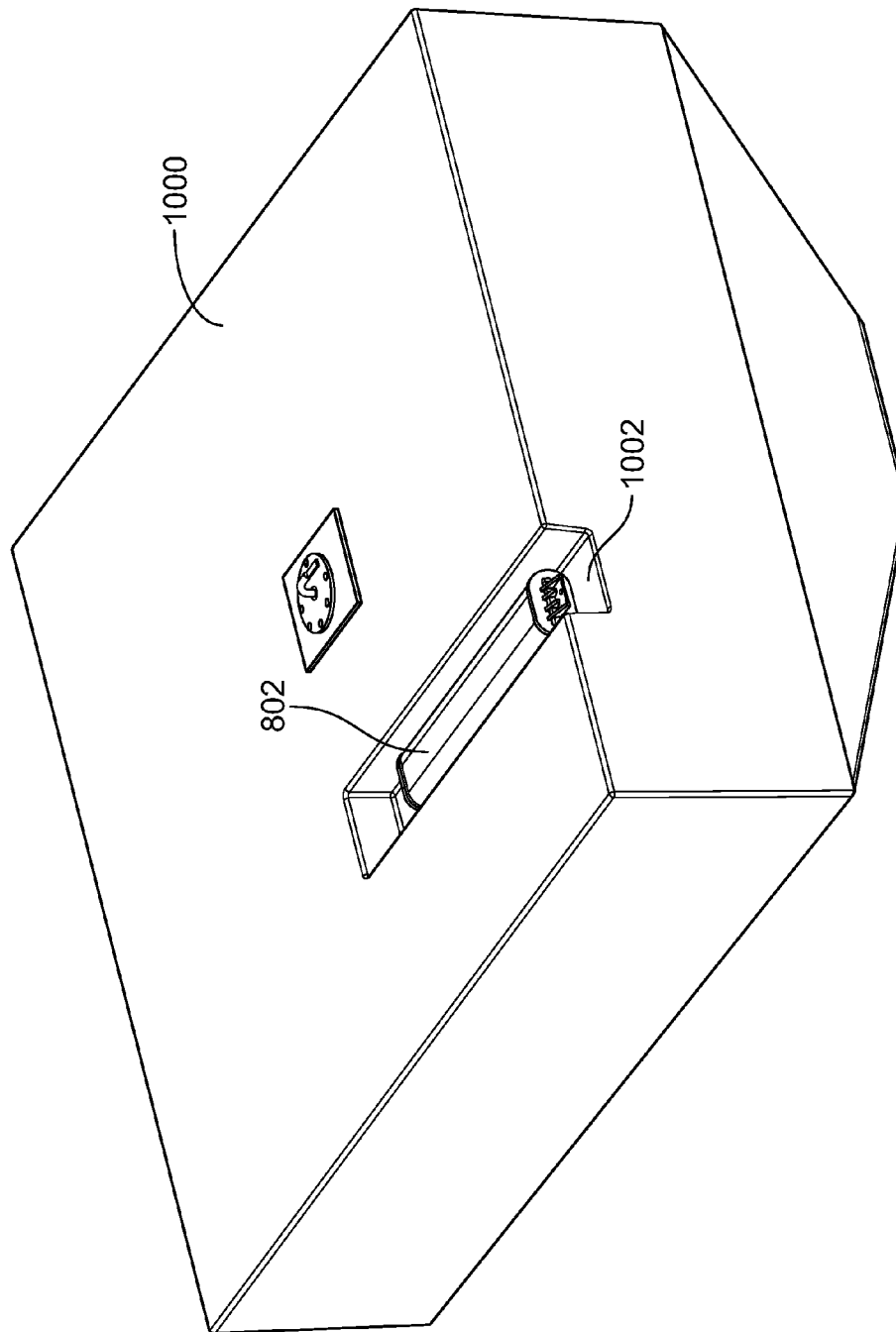


FIG. 10

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# PRESSURE RELIEF APPARATUS FOR USE WITH FUEL DELIVERY SYSTEMS

## CROSS REFERENCE TO RELATED APPLICATION

This patent claims the benefit of U.S. Provisional Patent Application Ser. No. 61/250,357, filed Oct. 9, 2009, entitled FUEL DELIVERY SYSTEMS HAVING IMPROVED EVAPORATIVE EMISSION CONTROLS, which is incorporated herein by reference in its entirety.

## FIELD OF THE DISCLOSURE

The present disclosure relates generally to fuel delivery systems and, more particularly, to pressure relief apparatus for use with fuel delivery systems.

## BACKGROUND

Governmental agencies (e.g., the Environmental Protection Agency) have enacted regulations to limit the amount of evaporative emissions emitted by boats and other marine crafts during operation and/or non-operation of the marine vehicle. More specifically, government regulations (e.g., title 40 of the Code of Federal Regulations) have been enacted toward controlling diurnal evaporative emissions of marine vehicles. In particular, these regulations limit the amount of evaporative diurnal emissions that a marine vehicle may permissibly emit during a diurnal cycle (e.g., periods of non-operation).

During non-operation of the marine vehicle, for example, a fuel delivery system of a marine vehicle may be subjected to daily ambient temperature changes that may cause the release of hydrocarbons to the environment. Such emissions are commonly referred to as diurnal emissions and are considered hazardous to the environment. Often, fuel or vapor leakage is exacerbated by diurnal temperature cycles. Diurnal emissions are evaporative emissions that are released due to the daily cycle of liquid fuel becoming fuel vapor during the daylight hours and condensing during the night. More specifically, during a diurnal cycle, the temperature of the air decreases during the night hours, causing the pressure of the fuel and/or fuel vapors in the fuel tank to decrease. When the pressure decreases, air is drawn into the fuel tank, which mixes with the fuel vapors. During the daylight hours, the temperature of the air may increase causing the pressure of the fuel and/or vapors in the fuel tank to increase. Such an increase in pressure causes fuel leakage or emission of fuel vapors via the fuel delivery system (e.g., a vent). For example, fuel leakage or emission of vapors may occur through a venting system of the fuel system and/or via permeation through various couplings (e.g., valves) of the fuel delivery system components.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is schematic representation of a known example fuel tank system.

FIGS. 2A-2B illustrate an example fuel delivery systems described herein.

FIGS. 3A-3C illustrate an example fuel cap assembly have a pressure relief system that may be used to implement the example fuel delivery systems of FIGS. 2A-2B.

FIGS. 4A-4B illustrate another example fuel delivery system described herein.

FIG. 5 illustrates yet another example fuel delivery system described herein.

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FIGS. 6A-6J illustrate an example insert material that may be used to implement to the example fuel delivery system of FIG. 5.

FIGS. 7A-7C illustrate an example fluid coupling that may be used to implement a fuel delivery system.

FIGS. 8A-8C illustrate yet another example fuel delivery system described herein.

FIGS. 9A and 9B illustrate an example fuel tank that may be used to implement the example fuel delivery system of FIGS. 8A-8C.

FIG. 10 illustrates yet another example fuel tank that may be used to implement the example fuel delivery system of FIGS. 8A-8C.

## DETAILED DESCRIPTION

In general, the example fuel delivery systems described herein may be used with marine crafts or vehicles. The example fuel delivery systems described herein include enhanced or improved evaporative emission apparatus to control or substantially reduce diurnal emissions. For example, the fuel delivery systems described herein may be configured to substantially reduce or prevent diurnal emissions through a venting system of the fuel delivery system when the pressure of the fuel within a fuel reservoir is below a predetermined pressure (e.g., 5 psi). In yet another example, the fuel delivery systems described herein substantially reduce or prevent diurnal emissions through various couplings (e.g., valves) of the fuel system components.

In some examples, the example fuel delivery systems described herein may be implemented with insert materials having low permeation characteristics or rates to substantially reduce permeation of emissions via various couplings (e.g., via one or more valve couplings) coupled to a fuel reservoir of the fuel delivery system. Additionally or alternatively, the fuel delivery system may include a fluid coupling to gauge the amount of liquid fuel in the fuel tank during a filling event and/or to prevent fuel spillage during a filling event or operation.

As used herein, a “fluid” includes, but is not limited to, a liquid such as fuel (e.g., gasoline), a vapor such as fuel vapor (e.g., gasoline vapor), a gas (e.g., air) and/or any combination or mixture thereof.

FIG. 1 illustrates a known marine fuel delivery system 100 having known evaporative emission controls. The example fuel delivery system 100 includes a fuel tank 102 for storing fuel (e.g., gasoline, diesel fuel, etc.), a filler tube 104, and a venting system 106 to vent the fuel tank 102. The filler tube 104 is coupled to the fuel tank 102 at a first port or coupling 108 and the venting system 106 is coupled to the fuel tank 102 at a second port or coupling 110. The filler tube 104 may include a deckfill 112 that is adapted for mounting to a deck of a marine craft such as, for example, a deck of a boat, and which has an opening for receiving a nozzle such as, for example, a nozzle of a fuel pump, etc.

In the example venting system 106, a tubular vent line 114 is coupled to the second port 110 of the fuel tank 102 at a first end 116 and vents to, for example, the atmosphere at a second end 118. The venting system 106 equalizes the pressure in the fuel tank 102 to accommodate volumetric changes (e.g., expansion) in the fuel tank 102. For example, when the pressure of fuel and/or vapors in the fuel tank 102 increases, fuel vapors are released from the fuel tank 102 through the tubular vent line 114. In other words, an increase in pressure in the fuel tank 102 causes fuel vapors (e.g., containing hydrocarbons) in the fuel tank 102 to vent or release to the atmosphere via the vent line 114.

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Additionally, during non-operation of the marine vehicle, the fuel delivery system **100** may be subjected to daily ambient temperature changes that may cause or affect the pressure of the fuel and/or fuel vapors within the fuel delivery system **100** (e.g., during diurnal temperature cycles). For example, an increase in fuel tank pressure may cause the release of hydrocarbons or gasoline to the environment. Diurnal emissions are evaporative emissions that are released due to daily temperature changes or cycles that may cause liquid fuel to become fuel vapor during the daylight hours and condensing fuel vapors to liquid during the night hours. As a result, the pressure cycling that occurs in response to these temperature changes causes the release of hydrocarbons from the fuel tank **102** to the environment via the vent line **114**.

Thus, the venting system **106** can continuously vent and/or emit emissions to the environment. Such a configuration may not be in compliance with certain governmental standards. For example, to be in compliance with governmental regulations enacted by the EPA, either the fuel tank **102** must be sealed according to certain standards (e.g., to prevent diurnal emissions when the pressure within the fuel tank **102** is below a predetermined value) or the fuel delivery system **100** must be provided with a vapor collection apparatus.

To help reduce venting liquid fuel, emissions, fuel vapors and/or pollutants to the environment, the venting system **106** may include various evaporative emission control components such as, for example, a vent apparatus **120**, a vapor collection apparatus **122**, and/or a surge protector **124** or a liquid-vapor separator **126**, which are coupled in fluid communication with the vent line **114**.

For example, the vapor collection apparatus **122** may be provided to passively filter emissions (e.g., hydrocarbons) from the fuel vapors venting to the atmosphere via the vent line **114**. The vapor collection apparatus **122** comprises a canister **128** having an emission(s)-capturing or filter material (e.g., an adsorbent material) such as, for example, activated carbon, charcoal, etc., that collects and stores evaporative emissions such as, for example, hydrocarbons to reduce pollution to the environment. The stored emissions captured and stored by the canister **128** are returned or carried to the fuel tank **102** as air flows through the canister **128** when the air is drawn from the atmosphere to the fuel tank **102** via the vent line **114**. However, the vapor collection apparatus **122** can be relatively expensive.

Additionally, the vapor collection apparatus **122** increases the overall dimensional footprint of the fuel delivery system **100** and/or is typically mounted at a remote location from the fuel tank **102** due to space limitations of the marine vehicle. Such a configuration requires additional or longer length tubing (e.g., a longer length vent line **114**), which may increase fuel leakage to the environment via the tubing and/or tubing couplings.

Additionally or alternatively, the fuel tank **102** lacks a liquid fuel level apparatus to determine the level of the fuel in the fuel tank **102**. As a result, the fuel tank **102** may be overfilled beyond a recommended amount. For example, regulations or a manufacturer recommendation may require a certain percentage of a vapor dome or ullage (e.g., a 5% ullage) when filling the fuel tank to allow for fuel expansion. However, when filling the fuel tank **102**, the example fuel delivery system **100** lacks an indicator to determine the liquid fuel level in the fuel tank **102** during the filling event or operation.

Additionally or alternatively, during a filling operation, as the fuel tank **102** is being filled via the deck fill **112**, the level of fuel stored in the fuel tank **102** rises. The fuel vapors in the fuel tank **102** are displaced and vented from the fuel tank **102**

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via the vent line **114**. Additionally, such displacement of the fuel vapors from the fuel tank **102** may cause the fuel vapors to carry liquid fuel through the vent line **114** and out to the environment through the vent apparatus **120**.

Thus, fuel leakage or overflow may occur via the filler line **104** and/or the vent line **114** during a filling operation. Such overflow can occur during filling when using a manually operated nozzle and/or an automatic nozzle when an automated shut-off is not activated. Such overflow typically occurs as the liquid level in the fuel tank approaches an upper, interior surface **134** of the fuel tank **102** (e.g., when the fuel tank is substantially full). As the liquid is filling in the fuel tank **102**, the liquid fuel is displacing the air and/or fuel vapors in the fuel tank **102** to the environment via for example the vent **120** and/or the filler tube **104**. As a result, the air and/or fuel vapors carry liquid fuel from the fuel tank **102** to, for example, the deck of the marine craft via the fuel fill tube **104** and/or the vent **120**, causing liquid fuel spillage.

Additionally or alternatively, diurnal emissions may occur via a fuel line **136** of the known fuel delivery system **100**. When the pressure in the fuel tank **102** increases during a diurnal cycle, the fuel vapors may fill the fuel line **136**. The fuel vapors may leak to the environment via permeation, couplings coupled to the fuel line **136** and/or the engine.

FIG. 2A illustrates an example marine fuel delivery system **200** described herein having improved evaporative emission controls. More specifically, the example fuel delivery system **200** described herein includes evaporative emission controls to meet or satisfy governmental diurnal emissions regulations (e.g., EPA regulations). The example fuel delivery system **200** of FIG. 2A includes a fuel tank **202** that is to be permanently mounted to a marine vehicle. However, in other examples, the fuel tank **202** may be a portable fuel tank (i.e., non-permanently mounted). The fuel tank **202** has a cavity or reservoir **204** to receive liquid fuel via a fuel fill or deckfill apparatus **206**.

As shown in FIG. 2A, the fuel delivery system **200** includes a venting system **208** fluidly coupled to the fuel tank **202** and the fuel fill apparatus **206**. The venting system **208** includes a first vent tube **210** to fluidly couple the fuel tank **202** to a vent or P-trap **212** and a second vent tube **214** to fluidly couple the fuel tank **202** to a vent **216** of the fuel fill apparatus **206**. The fuel fill apparatus **206** includes a fuel cap assembly **218** that removably couples from the fuel fill apparatus **206** to enable filling of the fuel tank **202** with liquid fuel. As described in greater detail below in connection with FIGS. 3A-3C, the fuel cap assembly **218** includes a pressure relief system (not shown) that is in fluid communication with the venting system **208** and the fuel tank **202**. Additionally or alternatively, in some examples, the vent **212** may also include a pressure relief system such as, for example, a pressure relief valve, a pressure relief system similar to the pressure relief system of FIGS. 3A-3C, and/or any other type of pressure relief apparatus.

In yet other examples, an example venting system **220** may include a pressure relief system disposed in-line with the vent tubes **210** and/or **214**. For example, a pressure relief valve **222** may be coupled to the vent tube **210** between the fuel tank **202** and the vent **212** instead of a vent **212** having a pressure relief system.

As shown in FIG. 2B, a fuel delivery system **200** may also include a venting system **224** having a vapor collection apparatus **226**. In this example, the vapor collection apparatus **226** is fluidly coupled to the fuel tank **202** at a first end or inlet **228** via tubing **230** and is fluidly coupled to the vent **212** at a second end or outlet **232** via tubing **234**. A vent tube **236** fluidly couples the outlet **232** of the vapor collection apparatus

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tus 226 to the vent 216 of the fuel fill apparatus 206. In this example, both the fuel cap assembly 218 and the vent 212 are implemented with pressure relief systems to provide a sealed fuel delivery system 200. However, in other examples, instead of the vent 112 having a pressure relief system, a pressure relief valve (not shown) may be coupled to the tubing 234 between the outlet 232 and the vent 112.

During a filling operation, the fuel cap assembly 218 is removed and the fuel tank 202 is vented via the vent tube 236. In this manner, the pressure relief systems of the vent 212 and/or the cap assembly 218 do not interfere with the functionality of an automatic nozzle. More specifically, the fuel cap assembly 218 is removed from the fuel fill apparatus 206 and the fuel tank 202 is vented via the tubing 236 and the vent 216 of the fuel fill apparatus 206. As described in greater detail below in connection with FIGS. 8A-8C, the vapor collection apparatus 226 may be mounted to the fuel tank 202.

In general, the venting systems described herein (e.g., the venting systems 208, 220 and/or 224) may be configured to prevent venting fuel vapors or gasses when the pressure of the fuel tank 202 is less than a predetermined pressure value relative to the atmospheric pressure and allow the flow of air to the fuel tank 202 when, for example, an engine (not shown) of a marine craft (not shown) demands fuel (e.g., during operation of the marine craft) from the fuel tank 202 or during a filling operation.

Thus, the example fuel delivery systems 200 provides diurnal emission control by only allowing the emissions of gasses and/or vapors (e.g., hydrocarbons) to the environment via the venting systems 208, 220 and/or 224 when the pressure of the fuel delivery system 200 (e.g., the pressure in the fuel tank 202) is greater than a predetermined pressure value (e.g., 1 psi) relative to atmospheric pressure and allows the flow of air to the fuel tank 202 when the pressure of the fuel within the fuel tank 202 is below a predetermined pressure relative to atmospheric pressure. Thus, in contrast to the known fuel delivery system 100 of FIG. 1, the fuel delivery system 200 include diurnal emission controls to prevent a continuous venting of fuel vapors to the atmosphere, thereby reducing the amount of emissions (e.g., hydrocarbons) released to the environment during, for example, a diurnal cycle.

In yet another example, the fuel delivery system 200 may include a fuel demand valve 240 disposed within a fuel line 242 between the fuel tank 202 and an engine (not shown). The fuel demand valve 240 fluidly decouples the pressurized fuel tank 202 from the engine fuel line 242 to reduce fuel leakage during the diurnal cycle (i.e., when the engine is not demanding fuel). Such an example fuel demand valve 238 is described in U.S. patent application Ser. No. 12/499,545, filed on Jul. 8, 2009, and entitled "A Fuel System for a Marine Vehicle", which is incorporated herein by reference in its entirety.

FIGS. 3A-3C illustrate the example fuel cap assembly 218 of the fuel delivery system 200 shown in FIGS. 2A and 2B. Referring to FIGS. 3A-3C, the fuel cap assembly 218 removably couples from the fuel fill apparatus 206 when filling the fuel tank 202 with fuel and provides a pressure relief system 300 when coupled to the fuel fill apparatus 206. The fuel cap assembly 218 can be made of fuel, weather and/or impact resistant resinous materials such as polypropylene, nylon, and/or any other suitable material(s).

As shown in this example, the fuel cap assembly 218 includes a cover 302 coupled to a body portion 304. In the illustrated example, the body portion 304 has a generally cylindrical shape extending along a longitudinal axis 306 that includes a central cavity 308 to define a first side or a pressure side 310 (i.e., a fuel side) and a second side or atmospheric

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side 312. When coupled to the fuel fill apparatus 206, the first side 310 of the body portion 304 is in fluid communication with the fuel (e.g., pressurized fuel) in the fuel tank 202 and the second side 312 of the body portion 304 is in fluid communication with the atmosphere. The body portion 304 may include threads 314 to threadably couple the fuel cap assembly 218 to a fill tube 316 of the fuel fill apparatus 206. The pressure relief system 300 includes a plurality of fluid valves.

In this example, the body portion 304 includes a first fluid valve 318 disposed within the central cavity 308 adjacent a second valve 320. The first fluid valve 318 has a first valve body 322 defining a first flow path between an inlet 324 in fluid communication with the first side 310 of the body portion 304 (e.g., the pressure side or a fuel tank side) and an outlet 326 in fluid communication with the second side 312 (e.g., the atmospheric side) of the body portion 304. Similarly, the second fluid valve 320 includes a second valve body 328 defining a second flow path between an inlet 330 in fluid communication with the second side 312 of the body portion 304 and an outlet 332 in fluid communication with the first side 310 of the body portion 304.

In the illustrated example, the inlet 324 of the first fluid valve 318 is oriented opposite the inlet 330 of the second fluid valve 320. In other words, the first fluid valve 318 enables fluid flow from the first side 310 to the second side 312 of the body portion 304 when the pressure differential from the first side 310 to the second side 312 across the first fluid valve 318 is greater than a reference or atmospheric pressure. Similarly, the second fluid valve 320 enables fluid from the second side 312 to the first side 310 of the body portion 304 when the pressure differential from the second side 312 to the first side 310 across the second fluid valve 320 is greater than a reference pressure or atmospheric pressure. In other words, the second valve 320 enables fluid flow between the inlet 330 and the outlet 332 when a pressure at the first side 310 is less than atmospheric pressure.

A flow control member 334 is disposed within the first passageway of the first valve body 322 and moves between a first position to prevent fluid flow (e.g., fuel vapors) between the inlet 324 and the outlet 326 and a second position to allow fluid flow between the inlet 324 and the outlet 326. A biasing element 336 (e.g., a spring) is disposed between a seat 338 (e.g., integrally formed with the flow control member 334) and a valve seat 340 of the first fluid valve 318. The biasing element 336 biases the flow control member 334 to the first position such that a seal 342 (e.g., an O-ring) disposed along a portion of the flow control member 334 sealingly engages the valve seat 340 to prevent fluid flow between the inlet 324 and the outlet 326. As shown, the seal 342 is disposed within an annular groove 344 of the flow control member 334. In this example, the flow control member 334 includes a pathway or passage 346 to fluidly couple a first side 348 of the seat 338 and the first side 310 to pressure-balance the flow control member 334 so that a relatively smaller biasing element may be used to bias the flow control member 334 toward the valve seat 340.

Likewise, a flow control member 350 is disposed within the second flow path of the second fluid valve 320 and moves between a first position to prevent fluid flow (e.g., air) between the inlet 330 and the outlet 332 and a second position to allow fluid flow between the inlet 330 and the outlet 332. A biasing element 352 is disposed between a spring seat 354 (e.g., integrally formed with the second flow control member 350) and a valve seat 356 of the second fluid valve 320. The biasing element 352 biases the flow control member 350 to the first position such that a seal 358 (e.g., an O-ring) disposed along a portion of the flow control member 350 sealingly

engages the valve seat **356** to prevent fluid flow between the inlet **330** and the outlet **332**. As shown, the seal **358** is disposed within an annular groove **360** of the flow control member **350**. Also, in this example, the flow control member **350** includes a passage **362** to pressure-balance the flow control member **350** so that a relatively smaller biasing element may be used to bias the flow control member **350** toward the valve seat **356**.

In this example, the valve bodies **322** and **328** of the respective first and second valves **318** and **320** protrude from a surface **364** of the body portion **304** within the cavity **308**. In this example, the valve bodies **322** and **328** and the respective valve seats **340** and **356** are integrally formed with the body portion **304** as a substantially unitary piece or structure. However, in other examples, the first and second fluid valves **318** and **320** may be separate structures that may be coupled or mounted to the body portion **304**. For example, the first and second fluid valves **318** and **320** may be pre-assembled and/or may be coupled to respective openings or passageways of the body portion **304** via fasteners, welding and/or any other fastening mechanism(s). In yet other examples, the fuel cap assembly **210** may include a plurality of the first fluid valves **318** and/or a plurality of the second fluid valves **320**.

In yet other examples, the first and/or second fluid valves **318** and **320** may include a ball valve and/or any other suitable valve configurations. In yet other examples, the fuel cap **218** may couple directly to (e.g., to a spigot of) a fuel tank (e.g., a portable fuel tank).

In this example, the body portion **304** includes at least one gap or passage **366** to allow the flow of gases between the second side **312** and an outer surface **368** of the cover **302**. The gap **366** is circumferentially spaced about the longitudinal axis **306** of the body portion **304**. However, in other example implementations, one or more gaps **366** may be spaced circumferentially on the body portion **304** and/or in any desired manner (e.g., unequal spacing).

The second side **312** and the cavity **308** are substantially covered or sealed via the cover **302**. Additionally, the outer surface **368** of the cover **302** has a convex contour or shape to repel and/or prevent liquid from entering the second side **312** of the body portion **304** (i.e., to allow water to run off cover **302**).

Additionally, a torturous pathway **370** is formed between the cover **302** and the body portion **304** to substantially prevent the ingress or egress liquid (e.g., fuel, water) through the gap **366**. In particular, any liquid fluid (e.g., water) would have to travel between a rim **372** of the cover **302** and the body portion **304** and, thus, the ingress and/or egress of liquid (e.g., fuel, water, etc.) and other contaminants is substantially prevented through the gap **366**. In the event liquid (e.g., water) or other contaminants pass through the gap **366**, the liquid is substantially captured by the cavity **308**. However, the torturous pathway **370** enables the flow of gasses or vapors (e.g., air, fuel vapors, etc.) between the gap **366** and the outer surface **368** of the cover **302**.

The cover **302** includes a plurality of protrusions **374** that engage a surface or edge **376** (e.g., a protrusion, a recessed groove etc.) of the body portion **304** to provide a tight fit and prevent the cover **302** from moving (e.g., wobbling) relative to the body portion **304**.

In operation, when the fuel cap assembly **218** is coupled to the fuel fill apparatus **206**, fuel vapors within the fuel tank **202** are relieved or vented via the first fluid valve **318** and atmospheric air may flow within the fuel tank **202** via the second fluid valve **320**. More specifically, during operation of the marine craft and/or during a diurnal cycle, the first fluid valve **318** allows the flow of gasses or fuel vapors between the inlet

**324** and the outlet **326** when the pressure at the first side **310** of the body portion **304** is more than a predetermined value (e.g., 1 psi, 5 psi) greater than the second side **312**, which is at atmospheric pressure. In other words, the first fluid valve **318** is in the closed position when the pressure at the first side **310** of the body portion **304** is less than a pressure required to overcome the spring force of the biasing element **336**. For example, the biasing element **336** may exert a force that moves the first fluid valve **318** to the closed position when the pressure of the fuel in the fuel delivery system **200** (e.g., the fuel tank **202**) is less than the predetermined pressure value. In one example, the first fluid valve **318** prevents venting when the pressure on the first side **310** of the body portion **302** is less than, for example, 1 psig and allows venting when the pressure on the first side **310** of the body portion **304** is greater than or equal to 1 psig.

During a diurnal cycle, for example, the pressure at the first side **310** of the body portion **304** may increase to a value greater than the predetermined value required to compress the biasing element **336** and move the flow control member **334** to the open position. When the pressure at the first side **310** is greater than the predetermined value, the pressure exerts a force on the flow control member **334** to move the flow control member **334** between the position shown in FIGS. 3A-3C and the second position in which the seal **342** moves away from the valve seat **340**. As a result, fuel vapors and/or gasses may flow or vent between the first side **310** of the body portion **304** and the second side **312** of the body portion **304** via the first fluid valve **318**. The vapors or gasses vent to the atmosphere via the gap **366** and the torturous pathway **370**. Also, the second fluid valve **320** remains in the closed position when a pressure at the first side **310** of the body portion **304** is greater than the pressure at the second side **312** of the body portion **304**. Thus, in contrast to the known fuel delivery system **100** of FIG. 1, the first fluid valve **318** prevents a continuous venting of fuel vapors to the atmosphere, thereby reducing the amount of emissions (e.g., hydrocarbons) released to the environment during, for example, a diurnal cycle.

During operation of the marine craft, the engine draws or demands liquid fuel from the fuel tank **202** via the fuel line **242**. The engine creates a vacuum or suction to draw the liquid fuel from the fuel tank **202** causing the pressure in the fuel tank **202** to decrease. Thus, air is required to enable the engine to draw liquid fuel from the fuel tank **202**. The second fluid valve **320** moves to an open position when the pressure differential across the second fluid valve **320** is such that the pressure at the first side **310** of the body portion **304** is less than the pressure at the second side **312** of the body portion **304**.

When there is a vacuum or suction created during operation of the engine such that the pressure at the first side **310** of the body portion **304** provides a force that is greater than the force exerted by the biasing element **352**, the flow control member **350** moves to an open position to allow the flow of air between the inlet **330** and the outlet **332**. In other words, the force exerted on the flow control member **350** in a direction toward the outlet **332** of the second fluid valve **320** is greater than the force exerted by the biasing element **352**, thereby causing the biasing element **352** to compress such that the flow control member **350** moves away from the valve seat **356** (i.e., downward in the orientation of FIGS. 3A-3C) to allow air flow between the inlet **330** and the outlet **332**. As illustrated, air (e.g., at atmospheric pressure) is allowed to flow within the fuel tank **202** via the gap **366** and the torturous pathway **370**. The gap **366** provides a pathway for fluid vapor or gas to travel between the fuel tank **202** (not shown) and the atmosphere.

To fill the fuel tank **202**, the fuel cap assembly **210** is removed from the fill tube **316**. When the fuel cap assembly **210** is removed from the fill tube **316**, fuel vapors and/or air pass through the vent **216** (e.g., via the vent tubes **208** or **236**) and/or the fill tube **316** to the atmosphere. Also, the first and the second fluid valves **318** and **320** are removed from the fuel delivery system **200** during the filling operation. In other words, the fuel cap assembly **218** operatively decouples the diurnal cycle venting functionality of the fluid valves **318** and **320** from the filling event or operation when the fuel cap assembly **218** is removed from the fill tube **316**. In this manner, the first and/or the second fluid valves **318** and **320** do not interfere with operational requirements of an automatic nozzle having a shut-off feature.

Automatic nozzles provide automatic shut-off by causing a valve of the fuel pump to close and prevent fuel flow via the nozzle during a filling operation. During a filling operation, automatic nozzles typically require a fuel tank pressure of less than 0.5 psi for the automatic shut-off feature to function or operate properly (e.g., a premature nozzle shut-off during a filling operation). Thus, although the pressure relief system **300** may be configured to vent at fuel tank pressures greater than, for example, 1 psig, the pressure relief system **300** does not interfere with the automatic nozzle because the pressure relief system **300** is operatively decoupled from the fuel delivery system **200** during the filling event. Once filling of the tank is complete, the cap assembly **218** is again coupled to the fill tube **316**.

Additionally or alternatively, although not shown, a deflection shield may be disposed within the fill tube **316** and/or may be coupled (e.g., integrally coupled) to the body portion **304** to deflect any liquid fuel traveling upwardly from the fuel tank **202** through the fill tube **316** in the event of a fuel surge caused by splashing or sloshing during boat movement or the like. In the event that liquid (e.g., fuel) bypasses the first and/or second valves **318** and **320**, the liquid must pass upwardly through the cavity **308** and in a succession of steps through the gap **366** and the torturous pathway **370**. In particular, the liquid fuel will be captured by the cavity **308**, thereby substantially preventing the liquid fuel from escaping and/or passing through the gap **366**.

In yet other examples, a membrane (e.g., a Teflon® membrane) may be implemented with the first fluid valve **318** and/or the second fluid valve **320**. For example, the membrane may be disposed within or adjacent the inlets **324** and **330**, the outlets **326** and **332**, the passageways of the valve bodies **322** and **328**, the gap **366**, and/or any other suitable portion of the fuel cap assembly **218**. The membrane enables the flow of gasses and/or vapors therethrough, but prevents the flow of liquid through the first fluid valve **318** and/or the second fluid valve **320**. In other words, a membrane may be disposed within the first fluid valve **318** and/or the second fluid valve **320** to prevent the ingress or egress of liquid or other contaminants and allow the flow of gasses therethrough. Such examples are described in U.S. patent application Ser. No. 12/061,163, filed Apr. 2, 2008, and entitled Fuel Cap Apparatus For Use With Fuel Venting Systems, which is hereby incorporated herein by reference in its entirety.

Additionally or alternatively, a membrane (e.g., a Teflon®) may be disposed within other components of the fuel delivery system **200**. For example, a membrane may be disposed within the vent tubes **210**, **214**, **230**, **234** and/or **236**, the vent **212**, the inlet **228** and/or the outlet **232** of the vapor collection apparatus **226**, and/or any other component of the fuel delivery system **200**. Such examples are described in U.S. patent application Ser. No. 12/391,782, filed Feb. 24, 2009, and

entitled Fuel Venting Systems Having Protective Membranes, which is hereby incorporated herein by reference.

Although not shown in detail, the vent **212** of the example fuel delivery system **200** may be implemented with the pressure relief system **300** shown in FIGS. 3A-3C, a pressure relief valve, and/or any other pressure relief apparatus.

FIG. 4A illustrates another example fuel delivery system **400** described herein. As shown, a fuel tank **402** includes a passage or coupling **404** to receive a plurality of components **406** of the fuel delivery system **400**. For example, the coupling **404** may receive a vent valve **408**, an anti-siphon valve **410**, a grade valve **412**, an inlet valve **414** of a fuel fill apparatus **416**, tubing, and/or any other components of the fuel delivery system **400** that is in fluid communication with and/or coupled to the fuel tank **402**. In this example, the coupling **404** comprises a plate having at least two apertures to receive the plurality of components **406**. Also, the coupling **404** provides a seal between an exterior of the fuel tank **402** and a cavity **418** of the fuel tank **402**. The coupling **404**, for example, may be coupled to the fuel tank **402** via a clamp and a compression gasket to provide a seal.

In this manner, the fuel tank **402** only requires a single opening or point of entry for the plurality of components **406** (e.g., valves and/or other components) by mounting or assembling the plurality of components **406** with the fuel tank **402** via the single coupling **404**. For example, at least a portion of the plurality of components **406** may be disposed within the cavity **418** of the fuel tank **402** via the coupling **404** and/or the plurality of components **406** may be mounted to the fuel tank **402** via the coupling **404**. In other words, the fuel tank **402** includes the cavity **418** to store a liquid fuel and includes only one opening or aperture in fluid communication with the cavity **418**. Additionally, in this example, the grade valve **412** is disposed within the cavity **418** of the fuel tank **402** at a distal end relative to the coupling **404**. For example, the grade valve **412** may be coupled to an interior surface **420** of the cavity **418** via a clip, a fastener, a chemical fastener, and/or any other suitable fastening mechanism(s). Tubing **422** fluidly couples the grade valve **412** to the vent valve **408**. The tubing **422** may also be coupled to the interior surface **420** of the fuel tank **402** via a clip, a fastener, etc. In this manner, the grade valve **412** is permanently coupled to the fuel tank **402** and is not serviceable.

As a result, only a single access or service point is required for inspection to satisfy government regulations that may require an access point to inspect (e.g., visually inspect) the coupling **404** of the fuel tank **402**. In other words, only one vehicle access panel may be required to enable access to the coupling **404**. Furthermore, only one mounting is required to mount the plurality of components **406** to the fuel tank **402**, thereby facilitating assembly of the fuel delivery system **400** and reducing manufacturing costs. Although not shown, the example fuel tank **402** includes an aperture to receive the coupling **404**. The fuel tank **404** may be formed via rotomolding, injection molding, blow molding, rotational molding, or any other suitable manufacturing process(es).

In other examples, as shown in FIG. 4B, a plurality of components **424**, tubing, or other fuel delivery system components may be coupled or mounted within the cavity **418** of the fuel tank **402** via the coupling **404**. In yet other examples, the coupling **404** can be used to implement other fuel tanks or fuel delivery systems. For example, the coupling **404** may be used to implement the example fuel tank **202** of the example fluid delivery system **200** of FIGS. 2A and 2B.

FIG. 5 illustrates the example fuel delivery system **400** of FIGS. 4A and 4B, but implemented with an example low permeation insert material or puck **500**. More specifically, the

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insert material **500** may be coupled to, disposed within, and/or embedded within a fuel tank **502**. The insert material **500** enables a coupling **504** (e.g., the vent valve **408** of FIG. **4**) to be coupled to a surface **506** of the fuel tank **502** via plastic welding (e.g., hot plate welding) to permanently attach the coupling **504** to the fuel tank **502**. Permanently attaching the coupling **504** to the fuel tank **502** eliminates the need to provide an access panel to visually inspect the coupling **504** because the coupling **504** is not serviceable, thereby reducing manufacturing costs of the marine vehicle while being in compliance with the governmental regulations. Additionally, the insert material **500** enables the coupling **504** (e.g., valves, etc.) to be attached to the fuel tank **502** via welding (e.g., plastic welding) while providing or maintaining a relatively low permeation characteristic.

Typically, the fuel tank **502** may be made of a thermoset material. Thermoset materials such as, for example, cross-linked Polyethylene typically have a high-temperature resistant property, a relatively high strength property, a relatively high resistance to chemical degradation, a relatively high impact and tensile strength characteristic, and are resistant to brittle fractures.

Although, such thermoset materials provide high temperature resistance, which is required to comply with certain governmental safety regulations (e.g., Title 33 of the Code of Federal Regulations), the coupling **504** cannot be attached to a surface (e.g., a surface of the fuel tank **102** of FIG. **1**) of a fuel tank made of a thermoset material via plastic welding (e.g., hot plate welding). Thus, such a coupling must be coupled via, for example, a clamp and compression gasket, a fastener, etc. Although these fastening mechanism(s) provide a reliable seal, these fastening mechanism(s) may cause leakage of fuel and/or vapors and, thus, may require access (e.g., via an access panel) for visual inspection to be in compliance with certain diurnal emissions regulations.

The insert material **500** may be integrally formed with, coupled to, embedded within, and/or disposed within the fuel tank **502** via, for example, blow molding, rotational molding, insert molding, and/or any other suitable manufacturing process(es). For example, the insert material **500** may be insert molded with the fuel tank **502**.

Further, in one example, to attach the coupling **504** to the fuel tank **502**, an opening is formed within the insert material (e.g. via a drill). The coupling **504** may include a thermoplastic end **508** (e.g., a flange) that may be coupled to the coupling **504** and/or may be integrally formed with the coupling **504**. The coupling **504** is disposed within the fuel tank **502** via the opening of the insert material **500** such that the end **508** of the coupling **504** substantially aligns with the insert material **500** of the fuel tank **502**. The end **508** and the insert material **500** are heated to a temperature above the melting temperature of material of the end **508** and the material of the insert material **500**. When the materials of the end **508** and the insert material **500** cool, the materials solidify or harden, thereby permanently attaching the coupling **504** to the fuel tank **502**. In other examples, the coupling **504** may be coupled to the fuel tank **502** via any other suitable method(s).

In another example, the fuel tank **502** may be implemented with the insert material **500** adjacent the coupling **404**. In this manner, the coupling **404** may be coupled to the fuel tank **502** via plastic welding. In this manner, welding the couplings **504** and/or **404** to the fuel tank **502** permanently fixes or attaches the coupling **504** and/or **404** to the fuel tank **502** and, thus, the plurality of components **406** and are not serviceable. As a result, access (e.g., via a vehicle panel) to the plurality of components **406** and/or couplings **404** and **504** may not be

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required per government regulations, thereby reducing manufacturing costs of the marine vehicle.

In another example, the fuel tank **402** of FIG. **4A** may be implemented with the insert material **500** adjacent the coupling **404**. As a result, in this example, the fuel tank **402** does not require an access for visual inspection and/or to service the coupling **404**. Additionally or alternatively, in other examples, a fuel tank (e.g., the fuel tank **102** of FIG. **1**) may be implemented with a plurality of insert materials **500** to enable a plurality of couplings or components (e.g., the couplings **108** and/or **110**) to be coupled to the fuel tank via plastic welding. For example, the plurality of components may include, but are not limited to, grade valves, vent valves, fill line inlet valves, anti-siphon valves, or any other component or coupling to be coupled to the fuel tank.

FIG. **6A** illustrates the example insert material **500** of FIG. **5**. FIG. **6B** illustrates a cross-section of the example insert material **500** of FIG. **6A**. Referring to FIGS. **5**, **6A** and **6B**, the insert material **500** includes a first layer material or barrier material **602** coupled to a second layer material **604**. In particular, the barrier material **602** is a copolymer material (e.g., Ethylene Vinyl Alcohol) having a low permeation characteristic or rate. In other words, the barrier material **602** has a high resistance to the passage of liquids and/or gasses there-through. Although the barrier material **602** has a low permeation characteristic, which is desirable to reduce leakage of emissions through the barrier material **602**, the barrier material **602** is incapable of supporting an attachment of a component via, for example, welding (e.g., hot plate welding). Coupling components (e.g., the coupling **504**) to the fuel tank **502** via welding substantially reduces or eliminates leakage or emissions where the coupling **504** attaches or couples to the fuel tank **502**.

The second layer material **604** is a thermoplastic material that enables attachment of the coupling **504** to the fuel tank **502** via welding (e.g., plastic welding, hot plate welding). Additionally, as shown in this example, a third layer material **606** comprising a thermoplastic material (e.g., High density Polyethylene) may be coupled to the barrier material **602** such that the barrier material **602** is disposed between the second and third layer materials **604** and **606**. Although the second layer material **604** and/or the third layer material **606** enable attachment of components via welding, fuel tanks made of thermoplastic materials are typically not permitted for use as integrated (i.e., permanently installed) fuel tanks because they have relatively low temperature resistance and, thus, do not comply with certain governmental standards (e.g., SCG Fire safety standards per CFR 33).

Thus, a fourth or outer layer material **608** made of a thermoset material may be disposed adjacent the second layer material **604** to provide an outer layer made of a thermoset layer material when integrated with the fuel tank **502**. Alternatively, the example insert material **500** may be implemented with a fuel tank made of thermoplastic material. Additionally, a fifth layer material **610** may be disposed adjacent the third layer material **606** to provide an interior layer of a thermoset material when integrated with the fuel tank **502**. Thus, the second and third layer materials **604** and **606** and the barrier material **602** may be captured or disposed between the layers **608** and **610**, which may be made of a thermoset material.

The barrier layer **602** may be any material having a low permeation characteristic or rate such as, for example, Ethylene Vinyl Alcohol (hereinafter EVOH), a petroseal material, and/or any other material having a relatively high barrier characteristic (i.e., a low permeation rate). An EVOH copolymer is defined by the mole percent (%) of the ethylene con-

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tent. Thus, the EVOH material can be configured to have a lower ethylene content grade to provide a higher barrier property or lower permeation characteristic. In some examples, the barrier layer **604** may include more than one layer and/or may be made of more than one different low permeation material.

The second and/or third layer materials **604** and **606** may be a thermoplastic material such as, for example, a high density polyethylene. In other examples, the thermoplastic material may be a polyvinyl chloride material, a nylon material, a polyurethane prepolymer material and/or any other thermoplastic material that softens when exposed to heat and returns to its original condition when cooled to room temperature. The thermoplastic material typically has a relatively low temperature melting point compared to the thermoset material. In some examples, the second layer material **604** may be made of a first thermoplastic material and the third layer material **606** may be made a second thermoplastic material different than the first thermoplastic material.

The second and/or third layer materials **604** and **606** enable a coupling (e.g., the coupling **504**) to be permanently coupled to the fuel tank **502** via, for example, welding. For example, to attach the coupling **504** to the fuel tank **502**, the second and/or the third layer materials **604** and **606** are heated to a temperature greater than the melting temperature of the thermoplastic material. In some examples, an end of the coupling **504** may also be heated (above the melting point) if made from a thermoplastic material. When the second and/or third layer materials **604** and **606** are heated above the melting temperature of the thermoplastic material, the second and/or third layer materials **604** and **606** melt or liquefy. The coupling **504** is disposed adjacent the second and/or third layer materials **604** and **606**. When the second and/or third layer materials **604** and **606** cool to room temperature, the second and/or third layer materials **604** and **606** solidify or harden, thereby permanently coupling or attaching the coupling **504** to the fuel tank **502**. Further, the barrier material **602** substantially surrounds and/or is embedded within the solidified or hardened second and/or third layer materials **604** and **606** to provide a barrier and prevent leakage of hydrocarbons from the fuel tank **502** to the environment via the point of attachment of the coupling **504**.

As noted above, the fourth and fifth layer materials **608** and/or **610** may be made of a thermoset material such as, for example, a cross-linked polyethylene copolymer. Such a cross-linked polyethylene copolymer provides resistance to high temperatures and high impact forces. In other examples, the layers **608** and/or **610** may be phenolics, polyesters, epoxies and/or any thermoset material that solidifies or sets irreversibly when heated (i.e., having high temperature characteristics) and has high impact characteristics. In some examples, the fourth layer material **608** may be made of a first thermoset material and the fifth layer material **610** may be made a second thermoset material different than the first thermoset material.

Additionally or alternatively, although not illustrated in the example, an adhesive or bonding agent may be disposed between any or all of the layers **602**, **604**, **606**, **608**, and/or **610** to facilitate adhesion between the different layers of material. For example, adhesion between the layers may be achieved via chemical bonding by including an adhesive material or agent on or in some or all of the layers **602-610**.

Thus, the example insert material **500** can be configured to provide a low permeation characteristic and has high temperature and impact resistance, while enabling permanent attachment of components such as valves via welding (e.g., hot plate welding). Additionally, the example insert material

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**500** may be configured in any suitable shape, profile, cross-section, pattern, etc. For example, FIGS. **6C-6J** illustrate the insert material **500** configured to have a variety of different orientations, cross-sections, profiles, patterns, etc. For example, the example insert material **500** may be implemented with only some of the layers **602-610** and/or any combination of the layers **602-610**.

FIGS. **7A-7C**, illustrate the example overflow prevention apparatus or fluid coupling **700** that may be used to implement a fuel delivery system such as, for example, the fuel delivery systems **100**, **200** and/or **400**. In this example, the fluid coupling **700** includes a first portion **702** fluidly coupled to a second portion **704** to define a liquid fill passage **706**. The fluid coupling **700** also includes a flange **708** between the first and second portions **702** and **704** to couple the fluid coupling **700** to a surface **710** of a fuel tank **712**. The flange **708** includes apertures **714** that receive fasteners (not shown) to couple the fluid coupling **700** to the fuel tank **712**. As shown, the first portion **702**, the second portion **704** and the flange **708** are integrally formed as a unitary structure.

However, in other examples, the first portion **702**, the second portion **704** and/or the flange **708** may be separate pieces that are coupled together via fasteners, chemical fastener or agents, and/or any other suitable fastening mechanism(s). In yet other examples in which the fuel tank **712** is made from a plastic material (e.g., a thermoset material, a thermoplastic material, etc.), the fuel tank **712** may include, for example, the insert material **500** to enable the fluid coupling **700** to be plastically welded to the surface **710** of the fuel tank **712** (e.g., via the flange **708**).

In this example, the first portion **702** has a cylindrically-shaped body coaxially aligned with the second portion **704**, which also has a cylindrically-shaped body. Additionally or alternatively, a first inner diameter **716** of a passageway **718** of the first portion **702** may be sized and/or shaped differently from, or substantially similar to, a diameter **720** of a passageway **722** of the second portion **704**. Additionally, the passageway **718** and/or the passageway **722** (and thus, the liquid fill passage **706**) may have a tapered profile, a hyperboloid-shaped profile, and/or any profiles. For example, a first portion of the passageway **718** may be sized different than a second portion of the passageway **718** and/or the passageway **722**. Although the example fluid coupling **700** is depicted as having a first cylindrical body and a second cylindrical body, the first portion **702** and/or the second portion **704** may have any other shape or geometry such as, for example, a square-shaped body, a rectangularly shaped body, and/or any other polygonal shape, etc.

The first portion **702** of the fluid coupling **700** is to be fluidly coupled to a fill tube **724** (e.g., the fill tube **316** of FIG. **3C**) or an inlet valve (e.g., the inlet valve **414** of FIG. **4A**) to receive a liquid (e.g., a fuel) via the liquid fill passage **706**. In some examples, the fluid coupling **700** may be integrally formed with the fill tube **724** and/or an inlet valve as a unitary piece or structure. The second portion **704** extends into a cavity **726** of the fuel tank **712** a predetermined distance **728** relative to an interior surface **730** of the fuel tank **712**. The second portion **704** has an aperture or opening **732** adjacent an end **734** of the second portion **704** to convey the liquid received via the liquid fill passage **706** to the cavity **726** of the fuel tank **712**. Although the opening **732** is shown as being coaxially aligned with the passageway **722**, in other examples, the opening **732** may be disposed along a surface of the second portion **704** such that the opening **732** is substantially perpendicular to the passageway **722**.

When coupled to the fuel tank **712**, the fluid coupling **700** provides a gauge to determine a level of liquid fuel **738** in a



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fuel tank 712 during a filling event. For example, some manufacturers recommend a certain amount of space or ullage 736 in the fuel tank 712. Additionally or alternatively, the fluid coupling 700 substantially reduces or prevents liquid fuel from overflowing to a deck of the boat during a filling operation via the fill tube 724.

In operation, when the fuel tank 712 is being filled, the volume or the level of liquid fuel 738 within the fuel tank 712 rises or increases. As the volume of the liquid fuel 738 in the fuel tank 712 increases, the vapors and/or air within the fuel tank 712 are vented or displaced via a vent or venting system 740. For example, the venting system 740 may be configured similar or identical to as the venting systems 208, 220 and/or 224 described above in connection with FIGS. 2A and 2B. As shown, the second elongate portion 704 is configured to extend into the cavity 726 of the fuel tank 712 the predetermined distance 728 to indicate the desired liquid fuel level within the fuel tank 712. In other words, the second portion 704 extends within the fuel tank 712 a distance that provides or correlates to a maximum desired liquid fuel level within the fuel tank 712. Additionally or alternatively, the second portion 704 prevents at least one of a gas or a vapor from flowing between the fuel tank 712 and the liquid fill passage 706 when the fuel in the fuel tank 712 is within or adjacent the opening 732.

For example, during a filling event, an automatic nozzle is fluidly coupled to the fluid coupling 700 via the fill tube 724. An automatic nozzle provides an automatic shut-off by causing a valve of the fuel pump to close and prevent fuel flow via the nozzle to the fuel tank 712 during a filling operation when a sensor coupled to the valve detects a certain pressure within the fuel tank 712. For example, when the sensor detects a pressure within the fuel tank 712 via the fill tube 724 that is greater than a predetermined pressure, the sensor causes the automatic nozzle to shut-off fluid flow.

Thus, as the liquid fuel 738 engages the opening 732 of the second portion 704, a back pressure is created within the liquid fill passage 706, which is fluidly coupled or in fluid communication (e.g., in direct fluid communication) with the nozzle via a passage 742 of the fill tube 724. Thus, the back pressure causes the sensor to trigger the automatic shut-off when the liquid fuel 738 reaches the desired level (i.e., the opening 732). Additionally or alternatively, the liquid fuel 738 may travel within the fill tube 724 and/or the vent 740, which can also trigger the sensor to shut-off flow from the nozzle.

Additionally or alternatively, the second portion 704 may include another aperture or bleed hole 744 between the end 734 and the interior surface 730 of the fuel tank 712. In this example, the bleed hole 744 is sized substantially smaller (e.g., has a smaller diameter) than the diameter of the opening 732 and has an axis that is substantially perpendicular to an axis of the liquid fill passage 706. When the automatic nozzle is triggered to shut-off due to the back pressure within the liquid fill passage 706 as the liquid fuel 738 reaches the opening 732, the bleed hole 744 enables the pressure (e.g., the backpressure) within the liquid fill passage 706 and the pressure within the fuel tank 712 to equalize. Additionally, the bleed hole 744 enables air to flow between the liquid fill passage 706 and the fuel tank 712 when the liquid fuel 738 expands due to thermal expansion and the liquid fuel 738 is adjacent the opening 732.

Although not shown, the vent 740 may also be implemented with the fluid coupling 700. Similarly, at least a portion of a fluid coupling coupled to the vent 740 may be at least partially disposed within the cavity 726 of the fuel tank 712 a predetermined distance to prevent at least one of a vapor or a

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gas from flowing to the atmosphere via the vent 740 when the liquid fuel 738 in the fuel tank 712 engages an opening (e.g., the opening 732) of the fluid coupling. A second end of a fluid coupling of the vent 740 may extend a predetermined distance within the fuel tank 712 that is substantially similar to or different from the predetermined distance 728 the second portion 704 of the fluid coupling 700 extends into the fuel tank 712 relative to the interior surface 730. The example fluid coupling 700 may also be used with known fuel delivery systems such as, for example, the fuel delivery system 100 shown in FIG. 1. For example, the fluid coupling 700 may be fluidly coupled to the fill tube 104 and/or the vent line 114.

FIGS. 8A-8C illustrate another example fuel delivery system 800 described herein. In this example, the fuel delivery system 800 includes a vapor collection apparatus 802 coupled or mounted to a fuel tank 804 (e.g., a permanently installable fuel tank or a portable fuel tank). The vapor collection apparatus 802 comprises a canister 806 disposed between an end 808a and an end 808b. The ends 808a and 808b capture the canister 806 so that a port or inlet 810 and a port or outlet 812 of the respective ends 808a and 808b form a pathway through the canister 806. The ends 808a and 808b include mounting brackets 814a and 814b that include respective apertures or openings 816a and 816b. The canister 806 includes an emission(s)-capturing or filter material (e.g., an adsorbent material) such as, for example, activated carbon, charcoal, etc., that collects and stores evaporative emissions such as, for example, hydrocarbons to reduce pollution to the environment.

The canister 806, for example, may be in fluid communication with the fuel tank 804 via the inlet 810 and may be in fluid communication with a vent 818 (e.g., the vent apparatus 212 of FIGS. 2A-2B) via the outlet 812. In this manner, fuel vapors entering the canister 806 through the inlet 810 from the fuel tank 804 pass through the filter material in the canister 806 before passing to the outlet 812 and, thus, the vent 818. The stored emissions captured and stored by the canister 806 are returned or carried to the fuel tank 804 as air flows through the canister 806 when the air is drawn from the atmosphere to the fuel tank 804 via a vent line 820. The canister 806 may be made of corrosion resistant materials such as, for example, thermoplastic polymers, stainless steel, aluminum, a combination thereof, and/or any other suitable material.

As more clearly shown in FIGS. 8B and 8C, the example vapor collection apparatus 802 is mounted to the fuel tank 804 via the ends 808a and 808b. In particular, the fuel tank 804 includes fasteners 822 such as, for example, a stud, a bolt, an internally threaded boss, and/or any other suitable fastening mechanism(s). The fasteners 822 may be integrally formed with the fuel tank 804. For example, the fuel tank 804 may include an internally threaded boss 824 protruding from a surface 826 of the fuel tank 804 and which may be integrally formed with the fuel tank 804 via blow molding, injection molding, rotational molding, and/or any other suitable process(es). A stud or screw (not shown) may be received by the apertures 816a and 816b and the boss 824 to attach or mount the vapor collection apparatus 802 to the fuel tank 804. Additionally, due to the proximity of the vapor collection apparatus 802 relative to the fuel tank 804, a shorter length tubing 828 can be used.

FIGS. 9A and 9B illustrate another example fuel tank 900 that can be used to implement the fuel delivery system 800 of FIGS. 8A-8C. The example fuel tank 900 includes a recessed portion or well 902 (e.g., integrally formed with the fuel tank 900) to receive the vapor collection apparatus 802. Additionally or alternatively, the recessed portion or well 902 may be dimensioned or sized (e.g., have a width) to receive the vapor

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collection apparatus **802** via interference or snap fit. The recessed portion **902** may be dimensioned or sized (e.g., have a depth) to enable the vapor collection apparatus **802** to be flush-mounted relative to a surface **904** of the fuel tank **900**. The recessed portion **902** includes fasteners (e.g., the fasteners **822** of FIGS. **8A-8C**) that may be integrally formed with the fuel tank **900** to couple the vapor collection apparatus **802** to the fuel tank **900** as described above in connection with FIGS. **8A-8C**.

FIG. **10** illustrates yet another example fuel tank **1000** that may be used to implement the example fuel delivery system **800** of FIGS. **8A-8C**. The example fuel tank **1000** of FIG. **10** includes a partial recessed portion **1002** to receive the vapor collection apparatus **802**. The partial recessed portion **1002** reduces less volume of the fuel tank **1000** compared to the recessed portion **902** of FIGS. **9A** and **9B** and, thus, enables the fuel tank **1000** to receive more fuel.

In some examples, although not shown, the recessed portions **902** and/or **1002** may include tabs or clips (e.g., integrally formed with the recessed portions **902** and **1002** of the respective fuel tanks **900** and **1000**) to enable the vapor collection apparatus **802** to couple to the fuel tanks **900** and **1000** via snap fit or interference fit. In some examples, the vapor collection apparatus **802** is coupled to the fuel tanks **900** and/or **1000** (e.g., within the respective recessed portion **902** and **1002**) via a band or clamping mechanism. In yet other examples, the fuel tanks **804**, **900** and/or **1000** may be implemented with the insert material **500** and a plastic fastener (e.g., a plastic stud, or internally threaded plastic boss, etc.) may be coupled to the fuel tanks **804**, **900** and/or **1000** via the insert material **500** and the methods described above in connection with FIGS. **5**, **6A-6J**.

The example vapor collection apparatus **802** and the fuel tanks **804**, **900** and **1000** facilitate mounting of the vapor collection apparatus **802**. For example, known vapor collection apparatus are typically mounted to a marine craft at a remote location from a fuel tank. For example, in contrast to the vapor collection apparatus **122** of FIG. **1**, the vapor collection apparatus **802** provides a compact dimensional envelope and/or decreases the overall dimensional footprint of a fuel delivery system implemented with the example fuel tanks **804**, **900** and/or **1000**. Additionally, such a configuration requires additional or shorter length tubing (e.g., the tubing **828**), which may decrease fuel leakage to the environment via the tubing and/or tubing coupling.

The example fuel delivery systems described herein may be combined or provided as a unitary or single fuel delivery system. For example, the venting systems **208**, **220** and/or **222** may be implemented with the fuel delivery system **400** of FIGS. **4A** and **4B**, the fuel delivery system **800**, and/or any combination thereof. Additionally or alternatively, the fuel cap apparatus **218** of FIGS. **2A** and **2B**, the insert material **500** of FIGS. **5**, **6A-6B**, the fluid coupling **700** of FIGS. **7A-7C**, the vapor collection apparatus **802** and the fuel tank **804** of FIGS. **8A-8C**, the fuel tank **900** of FIGS. **9A** and **9B**, and/or the fuel tank **1000** of FIG. **10** may be used to implement the fuel delivery system **100** of FIG. **1**, the fuel delivery system **200** of FIGS. **2A-2B**, the fuel delivery system **400** of FIG. **4**, and/or any other fuel delivery system(s).

Although certain apparatus, methods, and articles of manufacture have been described herein, the scope of coverage of this patent is not limited thereto. To the contrary, this patent covers all apparatus, methods, and articles of manufacture fairly falling within the scope of the appended claims either literally or under the doctrine of equivalents.

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We claim:

**1.** A pressure relief apparatus for use with a fuel cap, comprising:

a body defining a cavity and an annular wall projecting from a lower surface of the cavity, the cavity to receive or trap contaminants or liquid;

a pressure relief system coupled to the body to define a first side of the pressure relief system oriented toward atmosphere and a second side of the pressure relief system opposite the first side to be oriented toward a fuel tank, the pressure relief system having a first valve including a first valve body having a first end defining a first inlet oriented toward atmosphere and a second end defining a first outlet oriented toward the fuel tank, the first valve body housing a first flow control member to control fluid flow between the first inlet and the first outlet, the first valve body projecting from the lower surface of the cavity and toward an upper surface of the annular wall a distance substantially equal to a depth between the lower surface and the upper surface of the annular wall to prevent the contaminants or liquid in the cavity from flowing from the first side of the pressure relief system to the second side of the pressure relief system via the first inlet, the pressure relief system having a second valve body including a first end defining a second inlet oriented toward the fuel tank and a second end defining a second outlet oriented toward atmosphere and the cavity, the second valve body surrounding a second flow control member of the second valve along substantially an entire length of the second flow control member, the pressure relief system to enable fluid flow from the first side of the pressure relief system to the second side of the pressure relief system when a first pressure differential across the pressure relief system from the first side to the second side is greater than a first reference pressure, and the pressure relief system to enable fluid flow from the second side of the pressure relief system to the first side of the pressure relief system when a second pressure differential across the pressure relief system is greater than a second reference pressure.

**2.** A pressure relief apparatus of claim **1**, wherein the first valve body defines a first flow passage and the second valve body defines a second flow passage, the first and second valve bodies being integrally formed with the body.

**3.** A pressure relief apparatus of claim **2**, wherein the first valve includes the first flow control member disposed within the first flow passage and movable between a first position at which the first flow control member is spaced away from a valve seat of the first valve to enable fluid flow through the first flow passage and a second position at which the first flow control member sealingly engages the valve seat to prevent fluid flow through the first flow passage.

**4.** A pressure relief apparatus of claim **2**, wherein the second valve includes the second flow control member disposed within the second flow passage and movable between a first position at which the second flow control member is spaced away from a valve seat of the second valve to enable fluid flow through the second flow passage and a second position at which the second flow control member sealingly engages the valve seat to prevent fluid flow through the second passage.

**5.** A pressure relief apparatus of claim **1**, wherein the second side of the pressure relief system is to be in fluid communication with a fuel gas or vapor and the first side of the pressure relief system is in fluid communication with air at atmospheric pressure.

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6. A pressure relief apparatus of claim 5, wherein the first reference pressure comprises about 1 pound per square inch (psi).

7. A pressure relief apparatus of claim 5, wherein the second reference pressure is greater than atmospheric pressure.

8. A pressure relief apparatus of claim 1, wherein at least a portion of the first valve body or the second valve body is integrally formed with the body.

9. A pressure relief apparatus of claim 1, wherein the body includes a threaded portion to enable the body to be removably coupled to a fuel fill apparatus, wherein the body is removed from the fuel fill apparatus to operatively decouple the pressure relief apparatus from a fuel delivery system during a filling event.

10. A fuel cap apparatus, comprising:

a body defining a cavity between a lower surface and an annular wall projecting from the lower surface, the cavity to trap a contaminant or liquid;

a first valve having a first elongated body defining a first inlet to be in fluid communication with and oriented toward a fuel reservoir and a first outlet to be in fluid communication with atmospheric pressure and oriented toward the cavity, the first elongated body projecting from the lower surface of the cavity, the first valve having a first flow control member positioned in a first flow passage of the first elongated body and biased toward a first valve seat via a first biasing element, the first elongated body to substantially surround an entire length of the first flow control member between the first inlet and the first outlet, the first flow control member includes an annular groove to receive an O-ring that is to sealingly engage the first valve seat to substantially prevent fluid flow between the first inlet and the first outlet of the first valve, the first flow control member comprising a first passageway to pressure balance the first flow control member; and

a second valve having a second elongated body positioned adjacent the first valve and having a second inlet to be in fluid communication with atmospheric pressure and oriented toward the cavity and a second outlet to be in fluid communication with and oriented toward the fuel reservoir, the second elongated body projecting from the lower surface of the cavity and toward an upper surface of the annular wall defining the cavity a distance substantially equal to a depth between the lower surface and the upper surface to prevent the contaminants or liquid in the cavity from flowing through the second inlet and into the fuel reservoir, the second inlet being in fluid communication with the cavity, the second valve having a second flow control member positioned in a second flow passage of the second elongated body and biased toward a second valve seat via a second biasing element, the second flow control member includes an annular groove to receive an O-ring that is to sealingly engage the second valve seat to prevent fluid flow between the second inlet and the second outlet of the second valve, the second flow control member having a second passageway to pressure balance the second flow control member.

11. A fuel cap apparatus of claim 10, wherein the first valve and the second valve are at least partially integrally formed with the body of the fuel cap apparatus.

12. A fuel cap apparatus of claim 10, wherein the first valve enables fluid flow between the first inlet and the first outlet of the first valve when a pressure within the fuel reservoir is greater than a first predetermined pressure.

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13. A fuel cap apparatus of claim 12, wherein the first predetermined pressure is about 1 pound per square inch (psi).

14. A fuel cap apparatus of claim 10, wherein the second valve enables fluid flow between the second inlet and the second outlet of the second valve when a pressure within the reservoir is less than atmospheric pressure.

15. A pressure system of claim 10, wherein the first and second valves are operatively decoupled from the fuel reservoir during a filling event.

16. A pressure relief apparatus for use with a fuel delivery system, comprising:

means for defining a cavity to trap contaminants or impurities;

first means for controlling fluid flow from a first side of the pressure relief apparatus to a second side of the pressure relief apparatus when a pressure differential across the first means for controlling fluid flow from the first side to the second side is greater than a first predetermined reference pressure, the first means for controlling fluid flow projecting from a lower surface of the means for defining the cavity and toward an upper surface of the means for defining the cavity a distance substantially equal to a depth between the lower surface and the upper surface to prevent contaminants or impurities in the cavity from flowing through at least one of a first inlet or a first outlet defined by the first means for controlling fluid flow in fluid communication with the cavity; and

second means for controlling fluid flow from the second side of the pressure relief apparatus to the first side of the pressure relief apparatus when a pressure differential across the second means for controlling fluid flow from the second side to the first side is greater than a second predetermined reference pressure, the second means for controlling fluid flow positioned within a second means for defining a fluid flow path, the second means for defining the fluid flow path extending a distance substantially equal to a length of the second means for controlling fluid flow.

17. A pressure relief apparatus of claim 16, further comprising first means for moving the first means for controlling fluid flow between a first position to enable a gas or vapor to flow from the first side and to the second side when the pressure of the gas or vapor at the first side is greater than the first predetermined pressure, and a second position to prevent diurnal emissions of a gas or vapor from the first side to the second side when the pressure of the gas or vapor at the first side is less than the first predetermined pressure.

18. A pressure relief apparatus of claim 16, further comprising second means for moving the second means for controlling fluid flow between a first position to enable air to flow from the second side and to the first side when the pressure of a gas or vapor at the first side is less than atmospheric pressure, and a second position to prevent air flow from the second side to the first side when the pressure of the gas or vapor at the first side is greater than atmospheric pressure.

19. A pressure relief apparatus of claim 1, wherein the second valve body projects from the lower surface of the cavity and toward the upper surface of the annular wall a distance substantially equal to the depth between the lower surface and the upper surface of the annular wall.

20. A fuel cap apparatus of claim 3, wherein the first flow control member includes an annular groove to receive an O-ring that is to sealingly engage the valve seat to substantially prevent fluid flow between the first inlet and the first

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outlet of the first valve, the first flow control member comprising a first passageway to pressure balance the first flow control member.

21. A fuel cap apparatus of claim 4, wherein the second flow control member includes an annular groove to receive an O-ring that is to sealingly engage the valve seat to prevent fluid flow between the second inlet and the second outlet of the second valve, the second flow control member having a second passageway to pressure balance the second flow control member.

22. A fuel cap apparatus of claim 1, wherein the first flow control member comprises a first path and a second path to fluidly couple the first inlet and the first outlet, the first path to at least partially extend through the body of the first flow control member, the first path having a first axis that is substantially parallel relative to a longitudinal axis of the first flow control member, and second path having an axis that is non-parallel relative to the first axis.

23. A fuel cap apparatus of claim 3, wherein the valve seat is integrally formed with the first valve body.

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